DOE/DOT/1043-02

Potential Barriers to Electric Vehicle Commercialization
A. Insurance
B. Vehicle Recharging

March 1981

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16. Abstract

An assessment of the potential barriers to the commercialization of electric and hybrid vehicles due to insurance considerations and the absence of a range extension infrastructure was performed. Availability of operator and manufacturers liability insurance for the present small population of electric vehicles is not a major problem.

Many of the elements of the infrastructure needed to recharge a large number of electric vehicles in the U.S. are already in place. The major element of the refueling infrastructure for electric vehicles is range extension support. In the nearer term, development of a range extension hybrid, which could utilize the existing network of gasoline service stations, appears to be a feasible approach to this problem.

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PREFACE

This analysis was performed to assess the potential barriers to the commercialization of electric and hybrid vehicles due to insurance considerations and the absence of a range extension infrastructure, and to provide recommendations on possible actions that could be undertaken by the Federal government to overcome or minimize these barriers. These issues are examples of the institutional factors which Congress directed be analyzed in Section 13(a) of the Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976 (PL 94-413)

The assistance, support, cooperation and patience of Dr. Norman Rosenberg, the TSC Technical Monitor for this study, in the execution and completion of this study are gratefully acknowledged.

Preparation and completion of this study was a team effort, and the skill, enthusiasm and cooperation of everyone who participated in the program is gratefully acknowledged.

The study of Insurance Considerations was directed by Dr. Allan Bufferd, who is, among his many activities, a practicing attorney. He was supported in this effort by Dr. E. T. Kendall of the Commonwealth Research Group, Inc. of Boston, MA who performed a survey of selected Insurance Companies.

The analysis of electric vehicle recharging and range extension infrastructures was directed by the undersigned. Significant contributions to this study was made by the following team members from General Research Corporation of Santa Barbara, CA:

William F. Hamilton II	-	Range Extension Hybrid
Charles A. Graver	-	Battery Exchange Systems
Lynn Morecraft	-	Battery Exchange Systems
W. C. Harshberger	-	Cost of Recharge Facilities

Policy Analysis and Recommendations were performed by the undersigned with the assistance of Charles Hauer, Energy Consultant.

The assistance of Mrs. Eleanor Watson in the preparation of this document is also acknowledged and appreciated.

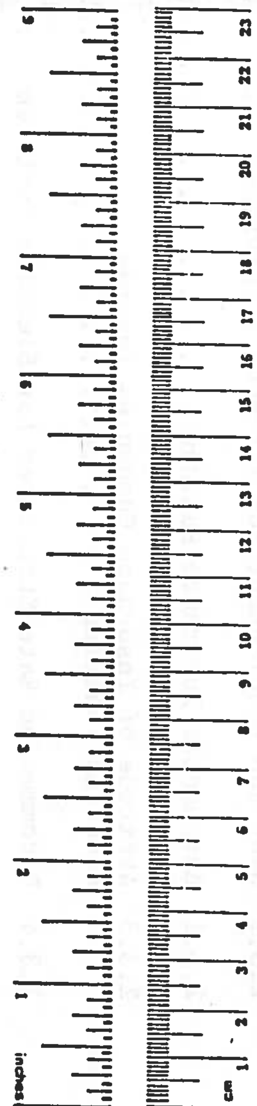
Robert Kaiser
Principal Investigator

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

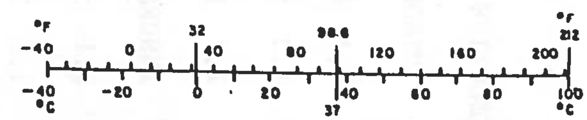
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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LIST OF ABBREVIATIONS

ADD	Accidental Death and Dismemberment
BI	Bodily Injury
CAFE	Corporate Average Fuel Economy
COLL	Collision
COMP	Comprehensive
DOE	Department of Energy
DOT	Department of Transportation
EHV	Electric Hybrid Vehicle
EV	Electric Vehicle
IC	Internal Combustion
ICE	Internal Combustion Engine
ICEV	Internal Combustion Engine Vehicle
KVA	Kilovolt-Ampere
MED	Medical Payments
PD	Property Damage
PIP	Personal Property Protection
SMSA	Standard Metropolitan Statistic Area
TOW	Towing
TSC	Transportation Systems Center
UM	Uninsured Motorist and Dismemberment
US	United States
ft	foot
gal	gallon
km	kilometer
kv	kilovolt
kW	kilowatt
kWh	kilowatt-hour
l	liter
mi	mile
mpg	miles per gallon
yr	year

EXECUTIVE SUMMARY

The objective of this study was to develop recommendations with regards to selected institutional barriers which would impede the commercial acceptance of electric and hybrid vehicles (EHVs). This study can be viewed as a continuation of the work initiated by the Transportation Systems Center in a prior study entitled "Institutional Factors in Transportation Systems and their Potential for Bias towards Vehicles of Particular Characteristics," DOE Report No. HCP/M1043-01. In the prior study, the seven institutional areas specified in Section 13(a) of PL 94-413 (The Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976), were reviewed and some sixty institutional factors were identified, characterized and evaluated.

The initial task of the present study was to review the institutional biases identified in the above referenced report to determine if the results obtained are still valid within the current socio-economic environment, and in the light of the results of other studies. This review entailed:

a. the identification and cursory analysis of the specific cause of each bias.

b. the identification of options for change, and of those specific changes that would eliminate or ameliorate the causes of bias.

c. an assessment of the relative importance of each bias to the EHV program under PL 94-413, and to the ultimate success of EHVx.

After this preliminary review, the following problem areas of potential bias were chosen for further study:

* Product liability and insurance considerations of EHVs.
* The absence of an electric vehicle recharging infrastructure, with special regards to range extension

The criteria for selection included:

* Importance of the potential bias in terms of the future use of EHVs.
* The "a priori" likelihood that the bias could be influenced by reasonable policy action.
* The suitability of the bias to study and to analysis.
* The inadequacy of prior studies on the topics of interest.

These institutional issues were explored in depth. Insurance carriers were interviewed, utility companies were contacted as well as municipalities, and landlords. Estimates of the cost of recharging together with the methods which could achieve electric vehicle range extension were made. Finally, appropriate costs to the federal government for various types of incentives to "even out" these biases in an economic sense were made.

Insurability and Insurance:

Findings: Owner/operators or EHVs have a need and a requirement for liability and accident insurance. The complexity of the insurance rating system relates to the availability of substantial data which have been accumulated with different automobiles and driver characteristics. While the insurance industry does not appear to have any serious negative bias toward providing owner insurance for EHVs, it does express some reservations about EHVs, and wants more information on performance characteristics, damageability and repairability. In particular, the insurance industry suggests that reliable information could be developed, for rating purposes, through the controlled distribution and monitoring of 5,000 to 10,000 EHVs.

The structure of product liability law and the increased awareness of consumers has created additional risks in recent years for manufacturers and sellers. This is especially true for consumer durable products such as the automobile. Product liability insurance or risk shifting is therefore necessary for those preparing to introduce the EHV to the consumer market. Particular issues include:

a) The structure of the industry: Current participants in the industry are typically small organizations. Product liability insurance is available to manufacturers, but such policies may not provide coverage for the life of a vehicle, or may include a cancellation clause with a short notice time provision. As a result, potential vendors (dealers) have noted resistance from their own insurers because the manufacturer has fewer financial resources than the vendor, thus exposing the vendor to the risk of becoming the "deep pocket" from which an injured consumer would seek recovery.

b) Battery Hazards: There are some unknown product hazards to be anticipated with the increased number of wet cell batteries in EHVs, and in the service and supporting structure for recharging, repair and maintenance.

c) Vehicle Performance: The performance characteristics of EHVs include limited speed and lower acceleration capacity than current ICE vehicles. This may result in a "design defect" determination under circumstances where such limited speed or lower acceleration capacity were directly related to physical harm incurred.

Policy Recommendations: At this time, it does not appear that an "insurance" policy action is required for the benefits of the manufacturer or the consumer. First, electric vehicle owners appear to be able to obtain insurance for liability, property damage, and collision on essentially the same terms as owners of ICE vehicles. There should be an improvement of the accuracy of the insurance rates as the federal demonstration program moves forward and there are more electric vehicles on the road. With regard to product liability for the manufacturers, it appears that this insurance is available, but at a cost which may result in a higher selling price for an EV or EHV. Since most electric vehicle manufacturers are relatively small with limited production, distributors and retailers may be discouraged, in the nearer term, from participating in the sales of EVs and EHVs because of the product liability question. This should not be an issue for the demonstration program under which vehicles are purchased directly from the manufacturer. Operation of EVs under the demonstration program will provide an experience base which will provide an improved basis for judging the product liability aspects of EVs. The impact of product liability considerations on the development of a retail dealer network should be reviewed in a few years, near the end of the demonstration program. At that time, liability insurance subsidies may be deemed appropriate. However, by then, major auto manufacturers might be interested in electric and hybrid vehicles, and may have joined with the existing smaller manufacturers through acquisition, which would make the product liability issue moot.

Electric Vehicle Recharging Infrastructure:

Findings: Many of the elements of an infrastructure required to recharge a large number of electric vehicles in the US are already in place. The US utility industry has sufficient capacity to support at least 13 million EVs, if they are recharged at night. There are at least 20 million single-family homes where it would be possible to recharge an EV by adding a branch circuit and outlet with a rating of 230 volts and 50 amperes. This support is not uniformly distributed, however, and will depend strongly on the characteristics of the local housing stock. The major element of the refueling infrastructure for EVs that is currently missing is range-extension support. Transient recharging stations would be of value for emergency recharging, but would not be desirable for routine use. Battery exchange would be a feasible alternative once there were enough EVs on the road to support a battery leasing operation and a network of exchange stations. The range-extension hybrid is a solution that could utilize the existing ICE refueling infrastructure, but would require further technical development, and would still depend somewhat on the availability of petroleum.

Policy Recommendations: In terms of the availability of electrical generating capacity to support a growing fleet of EHVs, it does not appear that federal action beyond that already mandated by the Public Utility Regulatory Policies Act (PURPA) of 1978 is required. Under PURPA, utilities are required to consider all possible actions to optimize load management. A growing fleet of EHVs will provide the utilities with an excellent load management tool.

One way of mitigating the consumer perceived disadvantage stemming from installing home base recharging facilities, would be to subsidize their cost. If this were done for fifteen years until the rate of introduction of battery powered vehicles were 400,000 units per year, the costs to the government would range between $18 million, at a 10% subsidy level, and $90 million, at a 50% subsidy level, and would apply to the installation of 1.7 million facilities. Such action, by itself, would not be sufficient incentive to accelerate the sale of EHV's as long as operating costs of battery powered vehicles remained significantly greater than those of comparable ICE vehicles.

The largest institutional barrier identified appears to be the lack of a range extension infrastructure for electric vehicles.

In the nearer term, as long as petroleum fuels are available, range extension through the development of a hybrid vehicle eliminates the problem of range extension infrastructure, permitting the use of existing gas stations, and can be implemented through continued funding of research and development of various types of hybrid vehicles. No action should be taken to develop a network of recharging stations for transient vehicles, except to provide tax credits, similar to those proposed for home base recharging facilities, for a very limited number of supervised recharging stations that could provide lifeline service for battery powered vehicles in distress. In the longer term, when hybrid vehicles could not operate for lack of petroleum fuel, and its distribution infrastructure, battery swapping could be a mode of providing range extension for all-battery vehicles. As a basis for incentives and cost estimates, it was assumed that incentive policies would reduce the total cost of energy per distance travelled for an electric vehicle (EV) to that of a fuel efficient internal combustion engine vehicle (ICEV). The total cost of energy for an EV is sum of the cost of electrical energy needed for propulsion as well as the cost of storing this energy on board the vehicle. The latter term is the cost of the battery. The total cost of energy for an ICEV is the cost of petroleum fuel consumed per distance travelled plus the cost of storing this fuel on board the vehicle. The latter term in the case of an ICEV is negligible. A seventeen year subsidy program which would support the leasing of batteries for 2.3 million EV's, is outlined, which given current prices, technology, and trends, would cost the Government approximately $380 million, in 1979 discounted dollars. Such a subsidy program would not be effective over the initial years of introduction of EV's because a critical vehicle fleet size would not be attained.

1. INTRODUCTION

1.1 BACKGROUND AND OBJECTIVE

A requirement of Section 13(a) of PL 94-413 (The Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976) is that a study be conducted ". . . to determine the existence of any tax, regulatory, traffic, urban design, rural electric or other institutional factor which tends or may tend to bias surface transportation systems towards vehicles or particular characteristics. . . . The report shall include any legislative or other recommendations. . . ."

In fulfillment of this requirement of the Act, a study was performed by the Transportation Systems Center (TSC) in which seven institutional areas specified in the Act were reviewed, and institutional factors that might be sources of bias were identified (1-1). Some 60 factors were characterized and evaluated, as outlined in Table 1-1. Of these, thirteen factors were judged to have major impact potential, with eleven of the thirteen being biased against electric vehicles.

Section 13(a) requires that recommendations on pertinent institutional factors be developed. The objective of the present study is to develop and analyze specific recommendations to ameliorate, or eliminate, negative biases against electric and hybrid vehicles, based on the results of the TSC institutional bias study (1-1).

1.2 SCOPE OF WORK UNDER THE CONTRACT

The initial task of the present study was to review the institutional biases identified in the TSC study (1-1) to determine if the results obtained are still valid within the current socio-economic environment, and in light of the results of other studies. This review entailed:

a. the identification and cursory analysis of the specific causes of each bias,

b. the identification of options for change, and of those specific changes that would eliminate or ameliorate the causes of bias,

c. an assessment of the relative importance of each bias to the EHV program under PL 94-413, and to the ultimate success of EHVs.

(1-1) N. Rosenberg, et al, "Institutional Factors in Transportation Systems and Their Potential for Bias Toward Vehicles of Particular Characteristics," DOE Report No. HCP/M1043-01, WC-96, December 1977.

TABLE 1-1 INSTITUTIONAL FACTORS MATRIX

SOURCE OF POTENTIAL BIAS / AREA OF IMPACT	TAXES AND REGULATIONS	TRAFFIC CONTROL	URBAN DESIGN	ELECTRICITY SUPPLY	FEDERAL POLICIES AND PROGRAMS	AUTOMOTIVE INDUSTRY STRUCTURE & PRACTICE	MISCELLANEOUS INSTITUTIONAL FACTORS
1. VEHICLE PRODUCTION AND DISTRIBUTION	o FEDERAL MOTOR VEHICLE SAFETY STANDARDS o FEDERAL MOTOR CARRIER SAFETY REGULATIONS o AIR POLLUTION CONTROL LAWS o FEDERAL NOISE STANDARDS o STATE NOISE CONTROL				o AUTOMOTIVE RESEARCH	o ECONOMIES OF SCALE o CAPITAL REQUIREMENTS o IN-PLACE INFRASTRUCTURE o RESEARCH & INNOVATION o PRICING	o OPEC o INTERNATIONAL ENERGY PROGRAM o MATERIAL CARTELS o CAPITAL AVAILABILITY
2. VEHICLE PURCHASE AND OWNERSHIP	o REGISTRATION FEES/ LAWS o SALES TAXES o PROPERTY TAXES o INSURANCE LAWS o INCOME TAX DEDUCTIONS o CUSTOMS AND TARIFFS o RURAL ELECTRIFICATION ACT		o URBAN DENSITY o PARKING AND CHARGING FACILITIES	o UTILITY CAPITAL o UTILITY REGULATIONS	o FLEET PROCUREMENT PROGRAMS o ENERGY RESEARCH		o INSURANCE AVAILABILITY o FINANCING AVAILABILITY o OPEC o INTERNATIONAL ENERGY PROGRAMS
3-A VEHICLE OPERATION-FUEL	o MOTOR FUEL TAXES o EMERGENCY PETROLEUM ALLOCATION o UTILITY TAX o ENERGY POLICY AND CONSERVATION ACT			o UTILITY RATES o ELECTRICITY DISTRIBUTION INFRASTRUCTURE			
3-B MAINTENANCE	o LUBRICATING TAX o TIRE & TUBE TAX o POLLUTION CONTROL LAWS			o BATTERY EXCHANGE			
3-C OPERATING CONDITIONS	o MINIMUM SPEED LAWS	o HIGHWAY TRAFFIC SPEED o HIGHWAY ACCESS RAMPS o TRAFFIC LIGHT TIMING o PREFERENTIAL TRAFFIC LANES o TOLLS AND CONGESTION PRICING o VEHICLE SEGREGATION POLICY	o INTERMODAL PLANNING o ACCESS POLICY o COVERED AUTOMOBILE FACILITIES				

Source: Ref. 1-1

After this preliminary review, the following two problem areas were selected for further analysis:

* Product Liability and Vehicle Operation Insurance for EHV's, and
* Absence of an Electric Vehicle Recharging Infrastructure

The criteria for selection included:

* The importance of the bias in terms of the future use of EHV's
* The "a priori" likelihood that the bias could be influenced by reasonable policy action.
* The suitability of the bias to study and analysis.
* The inadequacy of prior studies on the topics of interest.

Each of these potential sources of bias against electric and hybrid vehicles is analyzed in significant depth, and specific actions for change are proposed to overcome these biases. The impact of these proposed changes are analyzed in terms of their direct and indirect economic, social, environmental and institutional consequences. The most viable alternatives are specified as warranting further consideration for possible policy action.

Alternative policies for implementing the desired changes are developed, and evaluated against specific criteria, such as effectiveness in implementing change, and accomplishing a selected objective of introducing EHV's into every day use to a desired penetration level, political practicability, administrative feasibility, and economic cost, among others.

Broadly speaking, policy goals may be classified as:

- o Promotion of public safety and well being
- o Demonstration of the readiness of a new technology
- o Discouragement of the use of an alternate technology
- o Mitigation of risk for either manufacturer or consumer
- o Removal of financial inequities of the market place
- o Education of the public
- o Prohibition of certain courses of action

Policy tools that may be used to promote EHV's include

- o Inaction
- o Information programs
- o Development of standards
- o Research, Development and Demonstration Programs
- o Utilization of the purchasing power of the Government
- o Preferential tax treatment in the form of lower tax rates, depreciation schedules, tax credits, etc.

- o Government reinsurance programs
- o Low interest financing programs
- o Direct subsidies
- o Construction of facilities by the Government
- o Restriction of use of alternate modes of private transportation
- o Prohibition of alternate modes of private transportation

Combinations of policies that could be used to achieve the objective of accelerated introduction of EHV's into the market place are developed and proposed.

1.3 INITIAL REVIEW OF INSTITUTIONAL BIASES

The initial effort required was to review and update the findings of the TSC study (1-1). Table 1-2 lists the definitions established in Reference 1-1 for the terms Institutional factor and bias, and for the different types of vehicles and systems of interest to the study. The summary of the findings of the TSC study are presented as the first four columns of Table A-1 of Appendix A. In these columns each factor addressed is identified, the relevant vehicle characterisitcs (on which the analysis was based) are stated, the principal bias inputs are indicated and the measured value used in the analysis is listed.

This list of biases was reviewed to determine if they were still valid in light of information developed in other studies or to changes in laws and regulations in the time that had elapsed since the completion of the TSC study. It was noted that in two instances where a negative bias against EHV's was reported in Reference 1-1, changes in federal laws and regulations have taken place which have eliminated these biases. In the prior study it was noted that the Emergency Petroleum Allocation Act resulted in a negative bias against EHV's because it resulted in a controlled price for gasoline fuel in the U.S. that was less the average cost of imported crude oil. President Carter's announcement of April 5, 1979 that he intended to decontrol the price of domestic oil products between June 1, 1979 and October 1, 1981, and the subsequent enactment of the Crude Oil Windfall Profits Tax Act of 1980, have eliminated this point of bias.

In the TSC study, it was noted that the establishment of Corporate Average Fuel Economy (CAFE) Standards for manufacturers of internal combustion engined vehicles (ICEV's) under the Energy Policy and Conservation Act, resulted in a favorable bias towards electric vehicles since they were not

TABLE 1-2 DEFINITIONS

(1) Vehicle - a passenger or non-passenger automotive device propelled by electricity, hydrocarbon fuel or some hybrid system. This study is limited to vehicles with a gross vehicle weight of less than 10,000 lbs (4545 Kg) designed to operate on public highways. Vehicles not included are: forklifts and other commercial special purpose devices for carrying goods or for towing; recreational vehicles; mopeds; buses; and large vans and cargo carriers.

(2) Electric Vehicle (EV) - a vehicle powered by an electric motor drawing current from rechargeable storage batteries, fuel cells or other portable sources of electric durrent and which may include a non-electrical source of power designed to charge batteries and components thereof.

(3) Hybrid Vehicle (HV) - a vehicle powered by more than one energy source, one of which is electrical, and components thereof. For this study, a hybrid vehicle is defined more narrowly as one propelled by a combination of an electric motor and an internal combustion engine (EHV).

(4) Internal Combustion Engine Vehicle (ICEV) - a vehicle powered by the combustion in an internal combustion engine of a liquid fuel derived from petroleum.

(5) Institutional Factor - any policy, practice, regulation of infrastructure element that influences vehicle production, ownership and use. Institutional factors are grouped in terms of mechanism of influence, in accordance with the Act (i.e., tax, regulatory, traffic, urban design, rural electric, and others). Influences on vehicle production, ownership and use excluded by this definition are psychological and sociological factors, climatic and terrain aspects of the operating environment, safety factors, in short, those influences which are subjective, beyond influence or control or are dealt with in other studies.

(6) Bias - a leaning or inclination favoring (or discouraging) the production, ownership or use of an electric vehicle or hybrid vehicle relative to a vehicle equipped with an internal combustion engine as a result of the equal exercise of an institutional factor on the vehicle types being compared. To the greatest extent possible objective criteria are used in assessing bias consequence (e.g., dollar costs of production, ownership and use, functional market size, capital costs, etc). It is recognized, however, that some estimates of bias consequence are of necessity qualitative.

(7) Surface Transportation System - any automotive vehicle defined in terms of particular vehicle characteristics and functional markets.

included in the CAFE determination. Further work performed by the Aerospace Corporation (1-2) has indicated that non-inclusion of EHV's in the calculation of a company's CAFE rating actually resulted in a negative bias towards EHV's.

The development of improved IC engines and vehicles needed to meet the increasingly more stringent CAFE standards that would apply with each succeeding model year claimed the highest priority for R & D funds and personnel at the major automobile manufacturers. Leaving marketing questions aside, the non-inclusion of EHV's in a corporation's CAFE, in of itself, resulted in their being given a lower R & D priority. Sen. McLure's proposed modification of the Electric and Hybrid Vehicle Research, Development and Demonstration Act, which was incorporated as part of the Chrysler Corporation Loan Guarantee Act of 1979, has eliminated this particular bias. EHV's will be included in the calculation of a manufacturer's CAFE. Since the calculation of an equivalent petroleum based fuel economy for EHV's will include the ratio of electrical energy generated from petroleum to total electrical energy generation, EHV's will be classified as having extremely high values of fuel economy for purposes of CAFE calculations. This enactment results in a strong positive bias in favor of EHV's.

For those biases that were still perceived to be unfavorable to EHV's, options for change, and specific changes that would ameliorate or eliminate these causes of bias, were proposed to the extent possible. Where feasible, multiple options were proposed for the more severe biases. No changes were proposed for biases perceived to be favorable for EHV's.

The proposed options for change for the other negative biases were ranked according to the criteria outlined in Table 1-3. The ranking varied with the perceived ease of implementation of the proposed option - zero level being considered not feasible, first level being considered possible to accomplish, but with difficulty, and second level being considered feasible and relatively easy to accomplish. These proposed options were also rated according to the perceived need for, and level of, government intervention. The three levels were A, no government intervention required, B, onetime government action required, and C, continuing government action required.

(1-2) Richard T. Hall, "The Implications of Amending the Corporate Average Fuel Economy Standards to Include Electric and Hybrid Vehicles--A Preliminary Study," The Aerospace Corporation Eastern Technical Division, Mobile Systems Directorate, Washington, DC, 1979.

TABLE 1-3 RATINGS FOR OPTIONS FOR CHANGE

- 0 Not feasible under present socio-economic system.
- 1A Difficult to accomplish, but intervention by the government has no impact
- 2A Easily accomplished without government action.
- 1B Difficult to accomplish, with initial government action required.
- 2B Easily accomplished after initial government action.
- 1C Difficult to accomplish, and requires major continuing effort by the government.
- 2C Easily accomplished only after significant continued action on the part of the government.

Because of the widely diversified nature of possible biases, possible options for change were just as diverse, and could take on many different forms. Certain options for change were specific remedies for particular biases, while others may impact numerous biases. Furthermore, in the latter case these options may ameliorate or eliminate some biases, but aggravate others.

The proposed corrective actions, the option level assigned, and a short discussion are presented in the last three columns of Table A-1 of Appendix A. Table 1-4 is a summary of this preliminary analysis. No possible corrective actions are proposed in terms of Federal Policies and Programs (in that these were viewed as tools for bias elimination or alleviation rather than as sources of bias "per se"), and of automotive industry structure and practice (other than in terms of training of EV maintenance personnel), and international institutions (such as OPEC), because the scope and complexity of issues associated with these institutions were well beyond the scope of the preliminary analyses performed in this study.

A finding of this preliminary analysis as can be noted from examination of Table 1-4, is that the most effective way of providing a positive bias towards EHV's would be to create strong negative biases against ICEV's--either through taxation or restrictions on the availability of petroleum fuel. Examination of such options was not considered to be the intent of Congress in promulgating Section 13(a) of PL 94-413. The intent of Congress was interpreted to entail an identification and resolution of possible biases against EHV's because of the prior absence of such vehicles, rather than because of the prior presence of ICEV's. With this perspective, institutional biases created by the absence of data or information or EHV's, were considered as prime choices for further in-depth study.

In reviewing the long list of biases identified in Table A-1, the prior non-existance of an electric vehicle fleet of significant size results in significant institutional biases which would significantly curtail the operation of electric vehicles, as a means of personal or commercial transportation.

Owner/operators of automotive vehicles have a need and a requirement for liability and accident insurance. The availability and cost of such insurance are related to an insurance rating system which is based on the availability of substantial data which have been accumulated with different automobiles and drivers. The question of insurability of EHV's relates to the unknown

TABLE 1-4 SUMMARY OF PRELIMINARY ANALYSIS OF POSSIBLE GOVERNMENT ACTIONS

Category of Government Action		Government Has No Impact		Initial Action Needed		Continuing Action Needed	
Level of Difficulty	Not Feasible	Harder	Easier	Harder	Easier	Harder	Easier
Argos Numerical Rating	0	1A	2A	1B	2B	1C	2C
Issue	Possible Corrective Action						
Federal Taxes & Regulations							
Taxes				Increase Tax on Petroleum Fuels	Provide Income Tax Deductions/ Credits for EHVS		
				Impose Excise Taxes on ICEV's			
Safety Standards				Provide Relaxed Standards for EHV's			Support R&D for High Performance Materials
				Relax Standards for all Vehicles			
Air Pollution Standards				Provide for more stringent emission standards for ICEVs	Exclude EHV's from bans on auto usage in Regional Control Plans		
Petroleum Supply						Ration petroleum fuel for ICEVs	
Rural Electricity Administration					Include EHV's as qualified machinery under REA		Promote EHV's through REA
State Land & Regulations							
Taxes				Increase Taxes on Petroleum Fuels			
				Exempt EHV's from state/ local taxes	Federal Govt. provides credits to offset less in state revenues due to exemption of EHV's		

TABLE 1-4 SUMMARY OF PRELIMINARY ANALYSIS OF POSSIBLE GOVERNMENT ACTIONS (Continued)

Category of Government Action Level of Difficulty Argos Numerical Rating	Not Feasible 0	Government Has No Impact Harder 1A	Easier 2A	Initial Action Needed Harder 1B	Easier 2B	Continuing Action Needed Harder 1C	Easier 2C
Traffic Control							
Speed of Traffic	Modify Speed Laws to Accommodate slow moving vehicles (i.e. EHVs)			Provide Tax Credits for Private R&D on EHV's of Improved Performance			Promote strict enforcement of existing speed laws Upgrade performance of EHV's through Federal support of R&D
Highway Design	Rebuild Highway system to eliminate steep grades and ramps						
Traffic Flow	Reduce width of traffic lanes		Reset traffic signals to accommodate EHV's		Allow EHV's with one or two passengers in preferential access commuter lanes Provide low speed travel lanes for EHV's, bicycles, mopeds, etc.		
Urban Design							
Urban Density						Improve capabilities of EHV's through increased Federal support of R&D	
Intermodal Planning						Promote intermodal facilities to decrease auto commuting distances.	
Parking Supply			Promote Housing Codes that require off-street parking in multi-family residences	Promote Housing Codes that require electric outlets suitable for EHV recharge	Promote rate schedule proportional to vehicle size	Promote public recharging facilities	

TABLE 1-4 SUMMARY OF PRELIMINARY ANALYSIS OF POSSIBLE GOVERNMENT ACTIONS (Continued)

Category of Government Action Level of Difficulty Argos Numerical Rating	Not Feasible 0	Government Has No Impact Harder 1A	Government Has No Impact Easier 2A	Initial Action Needed Harder 1B	Initial Action Needed Easier 2B	Continuing Action Needed Harder 1C	Continuing Action Needed Easier 2C
Electricity Supply							
Cost of Electricity				Federal utilities provide special rates for EHV recharge			Structure demonstration programs to take advantage of favorable regional electricity prices
Availability of Generating Capacity				Relax Environmental Regulations on siting of new power plants	Provide Tax Credits to offset cost of home base recharging facilities		Promote off peak recharging of EHVs under PURPA
Availability of Vehicle Recharge Facilities				Provide tax credits for commercial recharging facilities	Provide Tax Credits to offset cost of home base recharging facilities	Build network of public EHV recharge stations Build network of battery exchange stations	
Vehicle Maintenance					Support training program for specialized technicians for EHV repair		Support/subsidize pilot EHV maintenance facilities
Product Liability and Vehicle Operator Insurance							
Provide data base to establish realistic rates	Require Federal contractors to purchase EHVs						Federal Agencies maximize purchase of EHVs Integrate EHV's into UMTA Structure Demonstration programs to provide statistically significant data
Availability of Insurance				Direct Federal Insurance Federal Reinsurance Assigned Risk Plans Mandatory Risk Pooling			

aspects of this new product and the lack of pertinent risk measurement data. In the absence of such information, there tends to be a tendency of insurers to either refuse to provide coverage, or to charge a premium that is sufficiently high to minimize their risk. Since many states require mandatory insurance coverage (through a surety company or by posting of a bond) as a pre-condition to registration, any hesitance of insurers to provide coverage would be a significant institutional bias against EHV's.

A related issue is the availability of product liability insurance for manufacturers and sellers of EHV's. The absence of data on the performance of EHV's in traffic, concerns about potential hazards due to the presence of batteries on the vehicle, and the fragmented structure of the EHV industry, have made the availability of such insurance an issue which would also result in a significant institutional bias against EHV's.

The other area of investigation chosen was the absence of an electric vehicle recharging structure. As electric vehicles have not been a significant factor in personal transportation up to now, the electric vehicle equivalent of the gasoline station is non-existent. The refueling support infrastructure of the thousands of gasoline stations in the Nation give internal combustion engined vehicles (ICEV's) effectively unlimited mobility and range. The lack of a range extension recharging infrastructure creates a clear bias against electric vehicles. It implies that EV owners must rely on private facilities, and limit their driving distances to the single charge range of the vehicle. Under these circumstances, ownership of an electric vehicle is limited to those individuals and organizations that have access to an off-street parking site which can be equipped with an electric outlet of sufficient rating to handle the recharging load of the vehicle. EVs are thus limited to the role of secondary vehicles for a restricted segment of the population.

2. INSURABILITY AND INSURANCE

2.1 SUMMARY

Owner/operators of EHV's have a requirement and a need for liability and accident insurance. The complexity of the insurance rating system relates to the availability of substantial data which have been accumulated with different automobiles and driver characteristics. While the insurance industry does not appear to have any serious negative bias toward providing owner insurance for EHV's, it does express some reservations about EHV's, and wants more information on performance characteristics, damageability and repairability. In particular, the insurance industry suggests that reliable information could be developed, for rating purposes, through the controlled distribution and monitorship of 5,000 to 10,000 EHV's. It would be necessary to review the position of insurers after such a demonstration program to assess the general applicability of the data base obtained.

The structure of product liability law and the increased awareness of consumers have created additional risks in recent years for manufacturers and sellers. This is especially true for consumer durable products such as the automobile. Product liability insurance or risk shifting is therefore necessary for those preparing to introduce the EHV to the consumer market. Particular issues include:

a) The Structure Of The Industry. Current participants in the industry are typically small organizations. Product liability insurance is available to manufacturers, but such policies may not provide coverage for the life of a vehicle, or may include a cancellation clause with a short notice time provision. As a result, some potential vendors (dealers) of EHV's have noted resistance from their own insurers because the manufacturer may have fewer financial resources than the vendor, thus exposing the vendor to the risk of becoming the "deep pocket" from which an injured consumer would seek recovery.

b) Battery Hazards. There are some unknown product hazards to be anticipated with the increased number of wet cell batteries in EHV's, and in the service and supporting structure for recharging, repaid and maintenance.

c) Vehicle Performance. The performance characteristics of EHV's include limited speed and lower acceleration capacity than current ICE vehicles. This may result in a "design defect" determination under circumstances where such limited speed or lower acceleration capacity were directly related to physical harm incurred.

2.2 INTRODUCTION

There is limited understanding of the owner/operator risk or of the product liability risk of the EHV. The resulting uncertainty in insurance availability, cost and protection was seen as a potentially serious negative bias to the introduction of EHV's. This section of the study was undertaken to develop a better understanding of the nature and extent of the institutional bias regarding the insurability of EHVs. Through an understanding of how risk is classified and measured, and how risk is managed within and for the automotive community, policy alternatives could be considered to ameliorate the institutional biases.

The objective of the study of insurability was to assess either the need for owner/operator protectiong to avoid the risk of substantial financial loss, or the state-imposed requirement for insurance. Additional objectives were to describe the insurance industry's assessment of owner/operator risk, to develop the industry's concerns and response to requests for EHV owner/operator insurance, and to evaluate selected policy alternatives to minimize or eliminate any institutional bias against the EHV.

The objective of the study of product liability was to assess the nature of the liability risk for small manufacturers, distributors and service providers in the EHV industry and to evaluate risk insurance or alternatives to protect against the financial loss which might result should the product (EHV) or service be found responsible for personal injury or property damage under the legal concept of product liability. The combination of strict liability with a product "defect", the absence of absolute protection from liability through adherence to government standards and the limited financial resources of the current manufacturers, distributors and service providers in the EHV industry creates a negative bias to the development and introduction of the EHV. There are no legal requirements for manufacturers, distributors and service providers to demonstrate financial assurance to compensate injured parties for losses incurred due to a "defective" product. Another objective was to evaluate whether public policy considerations require "defective" EHV products be withdrawn until the "defect" is removed.

Alternatives to limited EHV product liability risk and to provide sufficient financial resources to compensate for personal and property losses incurred were also considered.

2.3 OWNER/OPERATOR INSURANCE

The insurability of electric vehicles is subject to two pressures which influence the nature and extent of any institutional biases directed towards owner/operators. One pressure derives from the legal structure of automobile insurance among the different states. The other pressure derives from the position taken by the liability and casualty insurance industry towards providing necessary and required insurance and the rates charged. This section describes the need and requirement for automobile insurance for private passenger vehicles, the factors considered in automobile insurance ratings, the attitude of insurance companies toward electric vehicles, the recommended rate structure for electric vehicles and industry suggestions for the development of a data base for future insurance rating.

2.3.1 Need and Requirement for Automobile Insurance

The regulation of the insurance industry is distributed over the diverse jurisdictions of each of the fifty states. The limited federal role is shown by the McCarran-Ferguson Act, (2-1) adopted in 1945, which clearly established the regulation of insurance as being within the aegis of each of the states.

The concept of individual state control is important in attempting to fully describe the need and requirement for automobile insurance and the premium rates which are subject either to approval or to mandate by a state agency. The diverse requirements and premiums are designed basically to meet two major objectives, namely to assure that:

(1) the owner/operator responsible for an automobile accident does not face financial disaster if found liable,

(2) the victim of an automobile accident is appropriately compensated for personal and property damages.

States have adopted two overlapping aproaches towards meeting those objectives. The most general form is known as a "security-proof" financial responsibility act. (2-2)

In one form or another, financial responsibility laws have been adopted by all states and the District of Columbia. The important feature of these laws is that they apply to owners and operators only after the automobile is involved in an accident. A financial responsibility law generally requires that

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(2-1) 15 U.S.C. 1011, _et seq._

(2-2) M. G. Woodroof, _et al._, _Automobile Insurance and No-Fault_, Lawyers Co-Operative Publishing, 1978.

the owner or operator involved in an accident demonstrate, by posting security or proof of future responsibility, that he has sufficient financial responsibility to compensate the victims of the accident for personal and property loss where the owner/operator is deemed to be liable (at fault to third parties). The failure to adequately demonstrate such responsibility (most often evidenced by an insurance policy) results in revocation of the operator's license or, in some cases, the owner's automobile registration.

The threshold of applicability of the financial responsibility laws is low. Table 2-1 summarizes the minimum property damage level and the vehicles to which the respective laws apply. The applicability of these laws is further extended in twenty of the states which require some security or proof of financial responsibility whether the operator has been deemed at fault or not.

TABLE 2-1 APPLICABILITY OF FINANCIAL RESPONSIBILITY LAWS

Property Damage Level of Applicability

Property Damage	No. of States
$50 or $100	8
$150 or $200	18
$250 or $300	12
$350 to $500	4
No provision	9

Vehicles of Applicability

Type	No. of States
All vehicles involved in an accident	35
All vehicles required to be registered in state	9
No provision	7

The other approach taken by the states is compulsory liability insurance. This concept, started in Massachusetts in 1927, was based on the premise that, with all vehicles being covered by a liability policy, there would be no financially irresponsible drivers except for a few non-resident drivers on the state's roads and highways. No other states adopted a similar provision until New York did so in 1956 and then North Carolina in 1957.

There has been a significant extension of compulsory liability insurance during the 1970's. By 1979, 24 states had enacted compulsory liability laws which require, in one form or another, that financial responsibility protection be in effect on all registered vehicles regardless of involvement in an accident.

No-fault insurance, introduced in 1971, again first in Massachusetts, primarily addresses the objective of seeing that all victims of an automobile accident are compensated by their insurer for personal injuries, regardless of ability to prove fault. In some form or another, it is also a prerequisite to registration. The three basic categories of no-fault coverage are: (1) modified no-fault which eliminates a few fault-based claims, (2) add-on plans which provide minimal direct benefits to a victim without eliminating a right to press a fault-based claim, and (3) almost pure no-fault which eliminates almost all fault-based claims and provides almost unlimited benefits for medical expenses and lost wages. (2-3) By 1979, some form of no-fault had been adopted in 27 states.

Table 2-2 illustrates those states requiring financial responsibility coverage, compulsory liability or no-fault insurance.

The protection from the risk of financial loss associated with the responsibility for damage to the person and property of another (third party) is provided through liability insurance. The protection from the risk of financial loss to one's own person and property (first party) is provided through accident or casualty insurance.

The financial responsibility laws and compulsory liability insurance requirements are based on the obligations to a third party, generally for bodily injury and property damage. The protection mandated through no-fault insurance is primarily for first party bodily injury.

A brief and general description of the types of coverage provided through most standard forms of automobile insurance is shown in Table 2-3. However, it is difficult to make comparisons among the states as to the coverages

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(2-3) J. O'Connell, Operations of No-Fault Auto Laws: A Survey of the Surveys, Insurance Law Journal, 1977: 152.

TABLE 2-2 SUMMARY OF STATE AUTOMOBILE INSURANCE REQUIREMENTS (2-4)

State	Compulsory Liability	No-Fault and Add-On	Financial Responsibility
Alabama			*
Alaska			*
Arizona			*
Arkansas		*	*
California	*		*
Colorado	*	*	*
Connecticut	*	*	*
Delaware	*	*	*
District of Columbia			*
Florida		*	*
Georgia	*	*	*
Hawaii	*	*	*
Idaho	*		*
Illinois			*
Indiana			*
Iowa			*
Kansas	*	*	*
Kentucky	*	*	*
Louisiana	*		*
Maine			*
Maryland	*	*	*
Massachusetts	*	*	*
Michigan	*	*	*
Minnesota	*	*	*
Mississippi			*
Missouri			*
Montana	*		*
Nebraska			*
Nevada	*	*	*
New Hampshire		*	*
New Jersey	*	*	*
New York	*	*	*
North Carolina	*		*
North Dakota	*	*	*
Oklahoma	*		*
Ohio			*
Oregon	*	*	*
Pennsylvania	*	*	*
Rhode Island			*
South Carolina	*	*	*
South Dakota		*	*
Tennessee			*
Texas		*	*
Utah	*	*	*
Vermont			*
Virginia		*	*
Washington		*	*
West Virginia			*
Wisconsin		*	*
Wyoming			*
Total:	25	27	51

(2-4) Summary of Selected State Laws and Regulations Relating to Automobile Insurance, American Insurance Association, (1979), and Insurance Facts 1979, Insurance Information Institute, New York.

TABLE 2-3 AUTOMOTIVE INSURANCE COVERAGE (2-5)

Name	Acronymn	
Bodily Injury Liability	BI	Covers legal liability for bodily injury losses to others, with the amount of minimum coverage set by state law.
Property Damage Liability	PD	Covers legal liability for damage to the property of others, with and without fault.
Personal Injury Protection	PIP	Covers the insured's own income loss, medical expenses, loss of services and death benefits due to automobile accidents, with amounts determined by state law.
Uninsured Motorist and Dismemberment	UM	Covers bodily injury losses to the insured for accidents where an uninsured motorist was at fault, with minimums set by state law.
Accidental Death and Dismemberment	ADD	Covers death and dismemberment of the insured, regardless of fault.
Medical Payments	MED	Covers the medical expenses of the insured, which are due to automobile accidents, regardless of fault.
Collision	COLL	Covers loss to the insured automobile caused by collision, though sometimes dependent on fault.
Comprehensive	COMP	Covers loss to the insured automobile due to most causes other than collision (fire, theft, etc.).
Towing	TOW	Reimburses towing expenses.

(2-5) Carl Spetzler, et al., The Role of Risk Classifications in Property and Casualty Insurance: A Study of the Risk Assessment Process, Stanford Research Institute, 1976.

offered or to describe a reference coverage more specifically in that there are significant differences as to what coverage is required, the exclusions which are allowed, and the dollar amounts of liability or first party protection required as minimum.

Quite aside from any legal requirement for insurance, there is a need for insurance to be available if only to provide protection against the risk of financial loss due to involvement in an accident. With almost 28 million automobile accidents in 1978 (2-6), most owner/operators have a need for the protection provided through automobile insurance. The need is not only with regard to their own person and property but also to be protected from the risk of severe financial loss where the owner/operator is deemed to be liable for the injury to the person and property of others. The risk of this determination being adverse to one's interests also varies due to the diversity of tort law among the states, a factor which also affects the insurance liability rates.

Some individuals or organizations may have less need for insurance than others. This indicates that there is an ability to meet more of the risk of financial loss through their own resources. Examples of individuals or organizations in this category are those who purchase insurance with large deductibles --retaining the financial risk to the limit of the deductible, or those who have the capacity and willingness to self-insure--retaining the full financial risk. Where a state requires a demonstration of insurance coverage or financial responsibility, those wishing to completely self-insure can meet state requirements through the deposit of security.

Most owners/operators of EHV's therefore would have either a need or requirement for liability and accident insurance. The availability and rates charged for desired coverages is an area of potential concern.

2.3.2 Automobile Insurance Ratings

Recent studies (2-7 to 2-9) have examined the modern risk assessment process with a view towards assuring equity within the rate system. The complexity of the modern process is shown in Figure 2-1 and Figure 2-2 which depict those factors in the rating process for which statistical data exist in regard to expected accidents and to those factors in the underwriting process by which the insurance companies attempt to determine whether they wish to accept a particular risk. The historical development of automobile liability insurance

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(2-6) Insurance Information Institute and National Safety Council as reported in Insurance Facts 1979.

(2-7) Carl Spetzler, et al., The Role of Risk Classifications in Property and Casualty Insurance: A Study of the Risk Assessment Process, Stanford Research Institute, 1976.

(2-8) Automobile Insurance Risk Classification: Equity & Accuracy, Massachusetts Division of Insurance, 1978.

(2-9) D. J. Nye, et al., An Evaluation of Risk Classification Systems in Automobile Insurance, Florida Insurance Research Center, University of Florida, 1979.

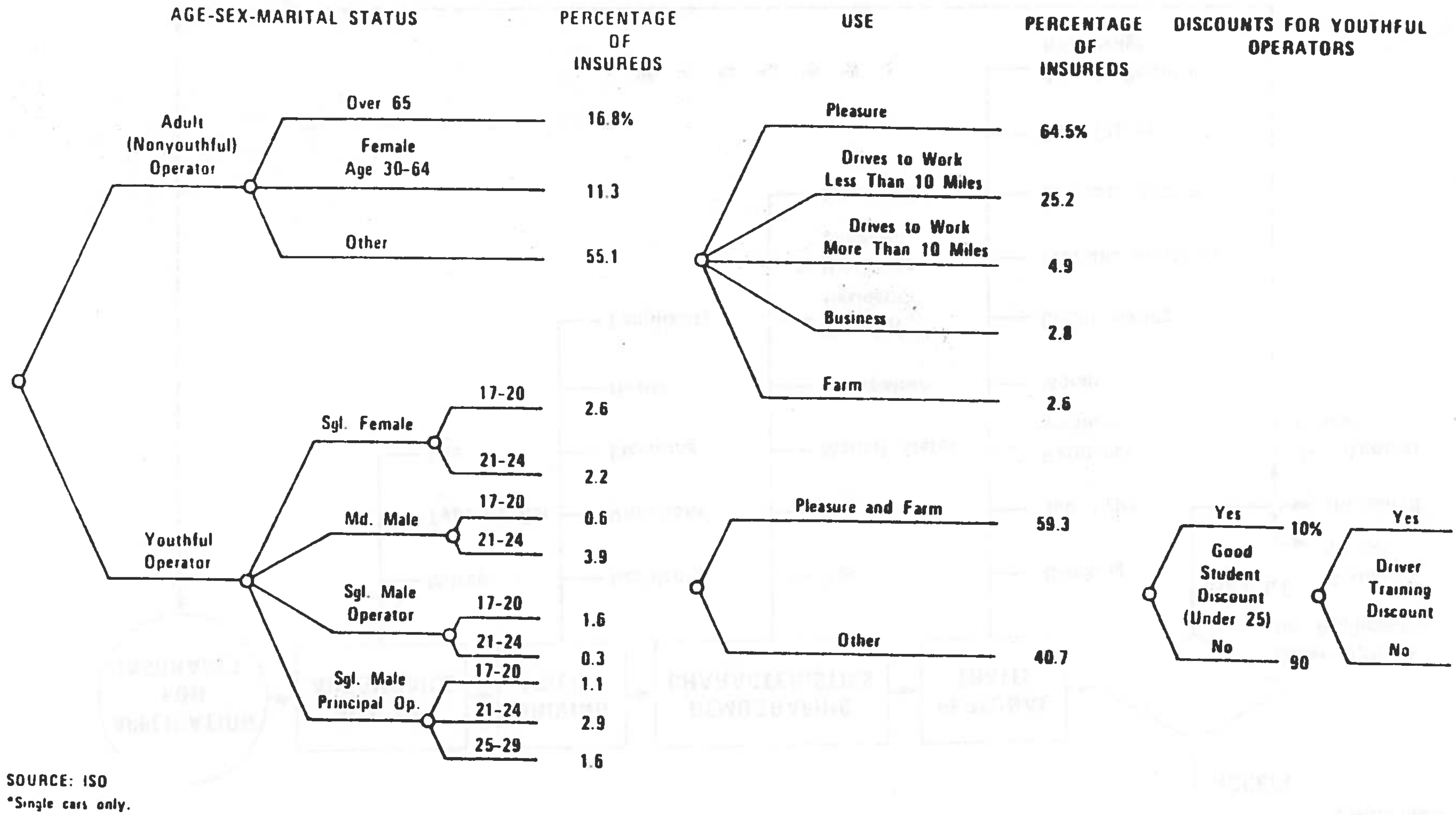

FIGURE 2-1 DISTRIBUTION OF RISKS BY CLASS: PRIMARY FACTORS (2-7)

(2-7) Carl Spetzler, et al, "The Role of Risk Classifications in Property and Casualty Insurance: A Study of the Risk Assessment Process", Stanford Research Institute, 1976.

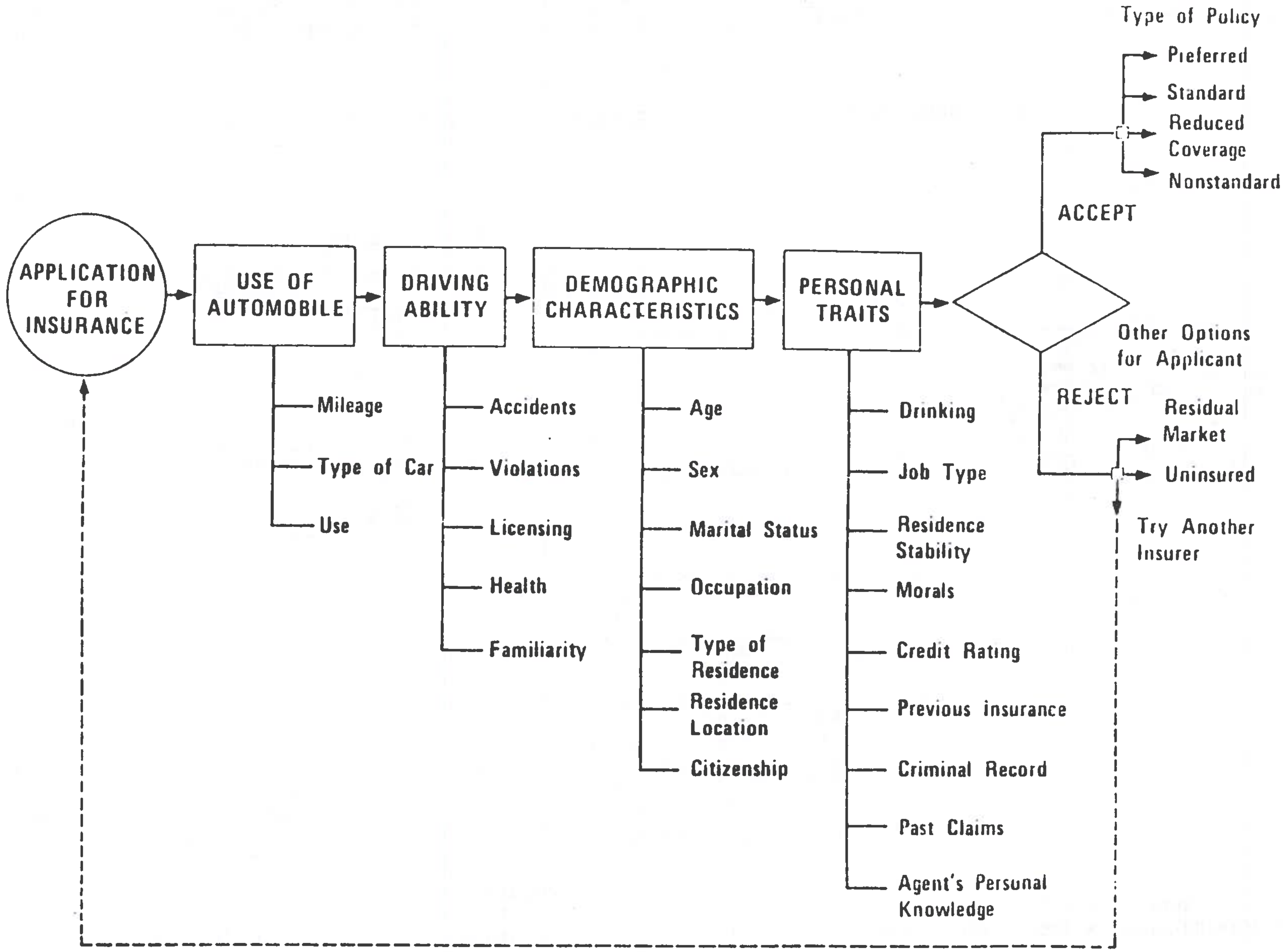

FIGURE 2-2 THE UNDERWRITING DECISION PROCESS

rates is described in Appendix B-1.

The insurer wants to select from applicants those whom it expects to be better risks than the overall average. While some states do not allow an insurer to refuse any applicant, most states do. The insurance applicant is either assigned to an insurance plan or accepted in the market by specialty carriers who cover higher risks at increased premiums. The Automobile Insurance Plans Service Office (AIPSO), a rating bureau, estimated that about 85% of the registered vehicles are insured, with high variability from state to state and with 70% of the registered vehicles in standard or preferred risk segments. The higher risk segment is primarily related to the owner/operator characteristics than to the automobile.

Rating factors based on the individual characteristics of the automobile (type of car, its age and use) have traditionally played a role in the underwriting process. With the current trend to question the precision of the rate assessment process as applied to individuals, an argument to flatten rates (eliminate distinctions between drivers) has resulted. This will probably create a pressure within the insurance sector to more closely examine the characteristics of the automobile to be insured, especially in regard to property damage as will be discussed below.

The most standardized aspect of insurance is the rate setting for physical damage to the automobile. Most of the rates are based on the age of the car, and the retail selling price. Where there may be unusual cost factors in repairability and damageability, the automobile might be rated in a higher category than age and selling price alone might indicate. Alternatively, special discounts might be provided for unique safety features designed to resist physical damage (improved bumpers) or theft (special locks). At the present time there is no uniform rate structure regarding property damage but test data and experience losses are resulting in more attention being directed to this area. Appendix B-2 summarizes examples of data available to describe repairability, damageability and incidence of claims for recent model automobiles.

The insurance industry has been considering other rating criteria than those typically in use. On November 15, 1979, the New York Times reported that The Motors Insurance Corporation, the 37th-largest insurer with more than 900,000 policyholders nationwide, would determine rates for its 2000 policyholders in Connecticut with an experimental Quality Driver Incentive Plan. The rates under this plan would be determined solely by the driver's record, the car being driven and the policyholder's address. A number of companies have started similar vehicle rating programs in over 20 other states to reflect differences in damageability, repairability and theft potential as based on actual experience. The Allstate Insurance Company, one of the largest insurers, which initiated such a program in 1976, recently announced its third revision of make and model experience rating (2-10).

In summary, the automotive insurance industry has, in the last 80 years, evolved a complex rate making system in which an enormous data system is tracking the accident experience of over 110 million vehicles. The system attempts to assess future losses on the characteristics of the operators, use of the vehicle and vehicle type as reflected in a claims experience of almost 28 million accidents in 1978 alone.

2.3.3 Attitude of Insurance Companies Towards Electric Vehicles

The automotive insurance industry is both large and diffuse. In 1978, the net premiums for automobile liability and property damage insurance totaled over 26 billion dollars for private passenger vehicles alone. The majority of this insurance was provided by about 900 companies out of the almost 3000 insurance companies providing some form of property and liability coverage (2-11). While the insurance industry has only limited experience with electric vehicles and such vehicles would represent only a small fraction of total vehicles insured for the near term, the need and requirement for automobile insurance, as described in Section 2.2.1, suggested contact with the industry regarding their experience and attitude towards electric vehicles.

Commonwealth Research Group, Inc. was retained to assist in a letter survey of major insurance firms regarding thier experience and attitude towards the insurability of electric vehicles. In addition, telephone and personal interviews were conducted with selected companies and rating organizations for a more extensive discussion of electric vehicle insurability.

The letter shown in Appendix B-3 was sent to the 51 largest insurance firms in the United States which provide automotive insurance. Of these, 29 responded. A summary of these replies, prepared by Commonwealth Research Group, Inc. is included as Appendix B-4.

(2-10) "Allstate cuts some premiums", Automotive News, October 22, 1979.

(2-11) Best's Aggregates and Averages as reported in Insurance Facts 1979, Insurance Information Institute, New York.

In addition to the summary, it is helpful in understanding the current industry view to note some comments extracted from the replies:

(i) "Electric and hybrid vehicles tend to be small, lightweight and slow. While these factors are not necessarily negative, vehicle safety is a major concern. Industry experience on small autos, for instance, shows a higher degree of damageability when compared to larger cars. The likelihood of a greater exposure to bodily injury must also be a consideration."

(ii) "We still have some reservations about insuring electric and hybrid vehicles designed for use on public highways....it is our understanding that at least some electric vehicles have a difficult time meeting the National Highway Safety Administrator's baseline safety standards."

(iii) "Due to the size of some of these vehicles, we could foresee a problem in the passenger hazard."

(iv) "(We) believe that the newer electric autos have better safety equipment (brakes, lights, etc.) and they are not very different than gas-powered autos."

(v) "....one of the great obstacles in providing favorable consideration would be the high repair costs one normally anticipates encountering when insuring any vehicle not subject to widespread use. Repair parts and facilities are often scarce or perhaps nonexistent. Many times the only source of satisfactory service is at the manufacturing point. Obviously, these considerations lead to a difficult insurance situation. Either the premium must be adjusted to meet the reality of the situation or the insurer must accept a risk at less than a satisfactory price."

(vi) "The multiplicity of units which seem to be appearing makes it difficult to be sure of sound, safe construction and safety systems....The lack of safety power reserve to accelerate when needed for crash avoidance is a detriment....Our main concern has been the lack of speed and power to cope safely with highway driving....If we do decide to insure them, it will be limited to the conventionally constructed, safe highway vehicle."

(vii) "...the physical damage coverages and premiums would depend upon whether or not the electric vehicle would cost more or less to repair."

(viii) "...we are still interested in data on their crashworthiness and damageability. The majority of these vehicles are in the sub-compact class which has developed poor results. Possibly, the lower speed capabilities of these vehicles will develop different results. However, the low speed presents different problems of creating traffic congestion on busy streets or secondary roads. Most freeways have minimum speeds higher than the maximum speeds of these vehicles, but if one should venture onto a freeway the results could be frightening."

(ix) "We would continue to use caution in affording Towing and Labor coverage and would have to carefully consider the availability of facilities for maintaining and repairing the vehicle."

(x) "...the repairability and the access of a repair shop would be of interest."

(xi) "We are most interested in being able to accumulate information on electric automobiles and other hybrid vehicles on an orderly basis well in advance of a possible widespread introduction of these vehicles."

In summary, we have a view of the insurance industry perspective which reflects two themes:

(1) Reservations regarding the insurability of the electric vehicle are based on lack of information.

(2) A need for more information on performance characteristics, damageability and repairability.

In reviewing the responses of the 29 companies, it is important to note that only one company stated that it would not insure electric vehicles. While the response of only 29 companies should not be the basis of too broad a generalization, it does seem as though no serious negative bias exists in regard to the need and requirement for owner/operator automobile insurance.

In fact, nine of the 29 companies indicated the adoption of a rate structure for electric vehicles which is more favorable than that experienced by ICEV's in the liability area. The basis of this more favorable liability rate will be discussed in Section 2.3.4.

None of the responding companies provided any indication of different rates for electric vehicles in regard to other forms of coverage than the liability coverages summarized in Table 2-3. For such other coverages, rates would be expected to be similar to that of similar sized ICEV's.

2.3.4 Recommended Rate Structures for Electric Vehicles

The most significant expense portion of automobile insurance is that associated with property damage, for both liability and accident protection [PD (Property Damage), COLL (Collision) and COMP (Comprehensive) in Table 2-3]. Accident insurance premiums for physical damage alone accounted for almost 40% of all private passenger property and liability premiums in 1978 (2-12). In addition, property damage liability premiums are typically two to three times

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(2-12) Best's Aggregates and Averages as reported in Insurance Facts 1979, Insurance Information Institute, New York.

the premium for bodily injury liability. (2-13)

Private discussions with representatives of the industry stressed only two areas of concern--liability for bodily injury and property damage, and accident insurance for property damage. The Insurance Services Office, a rating service described in Appendix B-4, provided more detailed comments about suggested rates in these areas.

The Insurance Services Office provides guidelines to insurance companies regarding premiums and relative risk assessments on all types of casualty insurance. Their suggested rates are filed for approval or guidance in all states except Massachusetts and Illinois. In late 1978, as part of a general update of selected portions of their manual, they published Rule 21F of their Personal Automobile manual as follows:

> "F. <u>Electric Autos</u>
>
> An electric auto is a motor vehicle of the private passenger type that is run by electric power and it is not used for commercial purposes.
>
> <u>Liability Coverages Only</u>
>
> Charge 75% of the applicable private passenger base premium.
>
> <u>Physical Damage Coverages Only</u>
>
> Charge the applicable private passenger base premium."

The update of the manual was only with regard to private passenger electrical vehicles; they had made no determination on commercial electric vehicles. The most significant aspect of their recommended rate is a reduced charge for liability coverage--bodily injury and property damage. The basis of the recommended reduction is their perception that the electrical vehicle has a more limited range and lower speed capacity than an ICEV and therefore a lower propensity to do damage to others.

The have indicated that Rule 21F is applicable in all states in which they operate except Mississippi, Wyoming and Maryland. The lack of applicability of the new rule to these three states relates to other aspects of the annual and not to the electric vehicle portion. Of particular interest is the basis for the suggested decrease in rates, rates which need not be adopted by subscribers to their manual: limited power, speed and range of the electric vehicle.

It is to be especially noted that the rate reduction is proposed for the liability sector only. At best, the industry, as indicated by this rating,

(2-13) Private Communication.

would treat the electric vehicle essentially equivalently on a national basis, to a gasoline or diesel engine automobile in regard to other coverages.

The Massachusetts rate for electric vehicles is not specifically identified but the state rating bureau indicates that it would view the vehicle as identical to a gasoline powered automobile while providing a similar 25% reduction in the liability rates in view of the limited speed and range.

2.3.5 Insurance Industry Suggestions

Direct discussions were held with underwriters of a few major insurance companies to learn those approaches that might be taken toward developing a reliable rate basis for electric vehicles and to explore further those issues which might affect an assessment of damageability and repairability.

In these discussions, the statistics comparing the Postal Service's accident experience with electric and internal combustion vehicles, as reported to a Special Senate Hearing, Role of Electric Vehicles in U.S. Transportation, by letter of June 13, 1979 (see Appendix B-5) were reviewed. While the results seem to suggest that the operators of the electric vehicles have experienced 40 to 60% of the accident frequency of the conventional vehicles, the underwriters raised numerous questions regarding those special factors which may have positively influenced the experience. Among these factors were the selection of drivers for the electric vehicles, driver training and the environment of use relative to that experienced by the conventional vehicles.

The expectation of the underwriters, reflected already in the suggested decrease in liability premiums relative to the gasoline powered vehicle proposed by the Inusrance Services Office, is that a limited range, lower speed capacity vehicle may have less propensity to do damage to others--a lower risk of liability.

However, the unknown is the extent of the physical damage the electric vehicle might experience and the cost to repair such damage. The present characteristics of the electric vehicle manufacturing, distribution and service resources are viewed as serious negative factors in estimating repair costs.

In noting the response to the letter survey (see Appendix B-4), the underwriters were asked to comment on the design of a program to acquire a sufficient data base which, in comparison to the experience of gasoline powered vehicles, might allow for a more reliable risk assessment and underwriting decision regarding electric vehicles.

With some disagreement as to the number of electric vehicles required to establish a sufficient data base, members of the industry suggested the following three program controls:

- ° Distribute electric vehicles initially to fleet operators (typically owners of five or more vehicles) to magnify the benefits of driver selection, driver training and to control the environment of use.
- ° Concentrate early fleet distribution of electric vehicles in areas of known territorial risk to develop adequate comparative experience.
- ° Minimize the distribution dispersion of electric vehicles so as to provide adequate maintenance and service support facilities.

Assuming careful selection of geographical area and of fleet operators, they thought that reliable experience could be developed with as few as 5,000 to 10,000 electric vehicles.

The underwriters suggested that existing data relating the ICEV experience of fleet operators to the general public could be the basis of a more generalized estimate for the private passenger EHV. Without the concentration in territory and environment of use, they questioned the reliability of appropriately assessing the insurance risk of 10,000 EHV's in a population of over 100 million vehicles.

Finally, representatives of the industry noted the importance of loss control as a major factor in the reduction of insurance costs. Loss control encompasses those measures which lead to a reduction in the probability that a loss will occur or to a reduction in the severity of an expected loss. Among the measures which could be taken to enhance loss control of electric vehicles are driver training, design features to minimize damageability and design and manufacturing features to ease repairability. The underwriters commented that the current program efforts under support of the Department of Energy to design and develop electric vehicles presented a unique opportunity for effective loss control programs.

If all the above conditions are met, one would have a data base which would be statistically representative of the operation of an EV fleet under the most favorable circumstances, i.e. in a relatively sheltered fleet environment with trained, professional drivers. Projecting this information to the operation of EV fleets in other geographical regions should be straight forward and present little potential risk to a potential insurer. However, there may well be some question as to the applicability of a data base obtained from the operation of EV's by individuals who would not be professional drivers, nor have the same training, skills and experience as fleet vehicle operators, and whose driving patterns would be very different.

Obtaining a data base from the operation of an EV demonstration fleet is a necessary first step. However, insurance companies should be contacted at the end of such a demonstration program to determine whether the data base so collected would be sufficient to allow them to establish insurance rates for the operation of EV's in other geographical areas, in terms of both fleet use and general personal transportation. If the experience obtained under the demonstration program were to show that EV's in fleet use are as safe, or safer, than ICE vehicles used in a similar environment, it may be possible that potential insurers might not be willing to apply this information to the formulation of insurance rates for EV's that would not be used in commercial fleets. The issue would become significant only if a consequence of the demonstration were to be the promotion of EV's as personal modes of transportation since as long as the number of EV's in private use remains small, the impact of insuring EV's on the operations of the insurers will remain small.

It may be necessary, even if EV's were to be shown as safe, or safer, than ICE vehicles in the initial fleet demonstration program, to consider a second program which would be designed around the use of EV's as a personal mode of transportation.

If the results of the initial fleet demonstration program indicate that an EV were an inherently less safe vehicle than an ICE vehicle in the same service, it would be necessary to reconsider the engineering of EV's used in the program, and modify the vehicle until the characteristics that would have led to a poorer accident record are eliminated. If it were to be shown, on a sound statistical basis, that EV's have a higher potential for accidents than ICE vehicles in the fleet demonstration program, which would be the best of all possible circumstances, it would be unlikely that potential insurers would willingly insure EV's on a general basis, and when they would, higher premiums reflecting the difference in accident potential would be applied. Under these circumstances, the application of higher premiums for EV's, or the unwillingness of insurers to underwrite them, would not be considered an institutional bias, but a reflection of the true performance of this alternate mode of transportation.

2.4 PRODUCT LIABILITY INSURANCE

The current structure of the EHV industry is primarily that of a new group of relatively small companies of limited manufacturing-experience whose efforts to date have met with minimal commercial viability. In addition, the EHV Research, Development, and Demonstration Act of 1976 specifically provides for the encouragement and protection of small business concerns to participate in the project. These two factors--the relative size of the manufacturers and the limited experience of the EHV industry--create a potentially major pressure for adequate product liability insurance, especially where the product under consideration is a consumer product. While there are no legal requirements for consumer product manufacturers or sellers to maintain liability insurance, consideration of the protection of injured parties suggests a need to assure adequate financial resources for compensation. This section describes the need for liability protection through a description of the characteristics of the liability; outlines the coverage and limitations of product liability insurance, its rate structure, and alternative risk shifting mechanisms; reviews recent major studies on product liability and describes some features of the EHV which may present unique liability risk.

2.4.1 Characteristics of Product Liability

Product liability is the term applied to that portion of the law dealing with the responsibility of manufacturers, distributors and sellers of products (hereinafter referred to as sellers) for the physical injury to persons and property of third parties. The nature of the liability is premised upon the concept that the seller of a product owes a duty of care not only to the product's immediate purchaser but to any user of the product and, where the injury is not too remotely related to a product defect, possibly even to a non-user bystander. In theory, the seller is in the best position to bear the risk of financial loss from the sale of a product which caused physical injury, either by insuring against losses or by absorbing such losses and then distributing the costs to the product users. Where the distributed costs for actual or anticipated losses make a product less market competitive the seller is induced either to improve the quality of the product or to remove the product from the marketplace. In those situations where the consuming public may be unprotected from product hazards, governmental mechanisms such as minimum product safety standards, mandatory product recalls or produce removals have been incorporated into the legal system through agencies such as the Consumer Product Safety Commission, the National Highway Traffic Safety Administration, the Occupational Safety and Health Administration, etc.

There are three legal concepts (discussed in Appendix B-6) under which an injured party may recover from a seller (manufacturer) for the harm due to the seller's product. The concept of strict liability is currently the most important of the three. This concept holds the seller liable for the damages resulting from a product defect, regardless of fault. While a seller may have defenses to the allegation of a product defect, mere compliance to a safety standard may be insufficient. The result is an enterprise risk for the seller, imputed to the seller by law under the view that the burden of the risk of accidental injuries should be distributed in the product cost. The result is a need for the seller to transfer the risk of that loss, most probably through product liability insurance, but also through other risk shifting alternatives.

2.4.2 Product Liability Insurance

The automobile has had a pivotal role in the development of product liability law and insurance. Starting with MacPherson v. Buick Motor Co. (2-14) in 1916, which extended protection to consumers who do not directly buy from the manufacturer when there are negligently built products that are "reasonably certain to place life and limb in peril", liability concepts have extended to the "second collision theory" where a manufacturer may be responsible for the enhanced injuries arising from a design or manufacturing defect which did not iteself cause the accident. (2-15)

Furthermore, the need for automobile manufacturers to have the ability to spread the product liability risk may be noted from a survey of one-million-dollar-plus jury awards in product liability cases in the 1966 to 1978 period. (2-16) Excluding those cases relating to defective tires, thirty-two of the fifty-nine awards of that size involved the automobile as the product.

One of the ways the liability risk may be spread is through the purchase of liability insurance. What then are the characteristics of product liability insurance and what are the factors that govern its availability and price?

Product liability insurance covers the liability of an insured for breach of warranty, negligence or strict liability which results in bodily injury or

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(2-14) MacPherson v. Buick Motor Company, 111 Northeastern 1050 (1916).

(2-15) Larsen v. General Motors Corporation, 391 Federal 2d 495 (Eighth Circuit 1969).

(2-16) Jury Verdict Research, Cleveland, Ohio as cited by G. Sullivan, Products Liability: Who Needs It?, The National Underwriter Company, Cincinnati (1979).

sustained by one or more persons as the result of one occurrence and an aggregate limit of $50,000; and for property damage there is a basic limit of $5,000 as the result of one occurrence and an aggregate limit of $25,000.

Among the more important exclusions and limitations of standard product liability coverage as they may apply to the EHV are (2-19):

(1) "Sistership" exclusion - This provision does not allow recovery for any damages claimed due to the recall or removal of products from the marketplace due to any known or suspected defect.

(2) Time Limitation - This provision restricts coverage to those bodily injuries or property damage which occur during the policy period. Therefore, the insurance in force at the time of the physical damage occurs is applicable rather than the insurance in force at the time the product was manufactured or sold. This results in the long-tail problem discussed below.

The long-tail problem associated with the time limitation of coverage relates to the fact that claims may be made against a seller after a policy is no longer in force, either through cancellation or through expiration, but involving an event which occurred during the policy period. This period between the occurrence and the claim is known as the "long-tail" (2-20). The greater this period is, the greater the difficulty for the insured and the insurer.

The insurer has to take in enough money during the policy period to cover those losses which may not be claimed until after termination of the policy. In addition, the dollars taken in as premium payments may depreciate during periods of high inflation prior to the claim. Both of these factors influence the insurer towards higher premium rates or even unavailability of coverage, especially where a long-tail may be perceived. It should also be noted that with a durable consumer product, such as an EHV, there may be a time lag between the date of manufacture and the occurrence, further compounding the problem. The insured is also presented with the uncertainty that when there is

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(2-19) Products Liability Insurance, Section 272.5, Policy, Form & Manual Analyses (1979).

(2-20) G. Sullivan, Products Liability: Who Needs It?, The National Underwriter Company, Cincinnati (1979).

a long-tail, the limits of coverage of the policy may have been less than what may be financially awarded against some future claim. Avoidance of this uncertainty through the purchase of additional insurance might be prohibitive on a rate basis. Alternatively, there may be no protection for insurance may be unavailable.

Some products liability insurance is being offered on a claims-made basis, where the time when the claim is made and not the occurrence governs the applicability of the insurance. However, such claims-made coverage might be viewed as being more favorable to the insurers for when a policy is cancelled or terminated, the insurer has no future claims to be concerned about and the insured may be unprotected unless other insurance can be obtained.

Aside from the costs of coverage and the question of availability, sellers may be required to retain a substantial portion of the potential liability for loss through an increase in required deductibles in order to assure coverage. Such a requirement is favorable to the larger sellers in that smaller organizations may not be able to bear the full risk of offered deductibles. For example, note the reported increase from one million to two million dollars in the deductible as Ford increased its liability coverage from fifty million to one hundred million dollars (2-21).

In general, the potential liability is less for the vendor of a product than for the manufacturers. (We will refer to the sub-group of wholesalers, distributors, and retailers as vendors.) Aside from protection that may be provided through their purchase of insurance, vendors are sometimes protected by major manufacturers purchasing, at extra cost, a vendor's endorsement as an addition to the manufacturer's policy. However, this does not provide complete protection for the vendor. The vendor only becomes an additional insured party on the manufacturer's policy, and the aggregate liability limits of the policy apply to all the insured parties, not to each individually. Furthermore, the vendor's coverage under the manufacturer's policy does not include protection for the vendor's failure to make adjustments, test or servicing of the product as agreed upon by the manufacturer and the vendor. The major value of a vendor's endorsement is that the volume of the vendor's sales of the product may be excluded from the sales volume factor in the product liability coverage of the vendor or be considered in providing a lower premium rate to the vendor.

(2-21) Business Insurance, July 24, 1978.

However, where a manufacturer has limited resources relative to its proposed vendors, the vendor may be forced to accept more product liability risk than that to which it was accustomed or the vendor might refuse to carry the product.

2.4.3 Product Liability Insurance Rate Structure

In 1976, under the direction of the United States Department of Commerce, an extensive review and report on product liability was prepared. (2-22) One of the major factors cited in the study for the product liability problems of industry were the rate making procedures of the insurance industry. As previously indicated, the setting of product liability rates was primarily based on the subjective judgement of the underwriter and, in most cases, even through the 1970's, product liability rates were incorporated within the total liability exposure determination for the insured on a composite rating technique. The result was that the rates for coverage were not easily determined as coverage was provided through a Comprehensive General Liability (CGL) policy.

Even with these composite rates, an insurance study prepared for the Task Force by McKinsey & Company, Inc. (2-23) was able to identify the risk criteria of the underwriters, to describe the industry practices and through a review of about 3000 underwriting files in six of the largest insurance companies and other sources, present data on product liability rates for eight industry sectors, including manufacturers of automobile components. Estimates of the rates for product liability insurance in the automotive sector are included in Appendix B-7.

Among the criteria cited in the report as being used by underwriters to evaluate a product liability risk, in conjunction with other liabilities, are:

- The exposure to loss in the insured's operations
- The loss control or safety measures practiced by the insured
- Prior losses experienced
- Financial stability of the insured
- The limits and coverages requested
- General underwriting guidelines

(2-22) Interagency Task Force on Product Liability PB-262-515, Briefing Report, (January 1977).

(2-23) McKinsey & Company, Inc., Final Report of the Insurance Study - Volume I, Interagency Task Force on Product Liability PB-263-600, ITFPL-77/03 (1977).

The uncertainty of risk determination for small companies with little or no product history is evident. However, while the study noted the difficulties faced by the smaller companies, especially for durable products (note that coverage applies to the time of occurrence not time of manufacture), the following practices were noted:

- A primary insurer would provide aggregate products liability coverage to an amount in the $250,000 to $1,000,000 range.
- Excess coverage above the primary amount would be provided by other insurers or through reinsurance.
- There is limited state regulation of product liability insurance rates based on the view that insurers who provide a wide range of coverage for commercial risks need more flexibility than insurers of personal lines of coverage where the view is to protect the individual consumer (owner/operator automobile insurer).

One factor not considered in the study of rates is the potential impact on the rates when the insured retains some risk through the use of deductibles. In general the more risk the insured retains, the lower the insurance rate.

However, the benefits in reduced rates through retention by small companies may not be significant. The insurance industry considers the financial capacity of an organization to retain risk of loss on an annual aggregate basis to be one of the following:

- 1% of net working capital
- 1% of current surplus, plus 1 percent of the average earnings over the past 5 years
- 0.1% of net sales

Since the Task Force study, efforts have been initiated in the insurance industry and the Insurance Services Office (ISO) to more specifically establish liability rates by product category on an actuarial basis.

One of the major findings of the Task Force is that while rates tend to increase with increased levels of coverage and that smaller organizations have experienced significant rate increases, the product liability "crisis" is not one of the availability of insurance. Furthermore, the pressures which tend to threaten the viability of small companies relate to their limited capacity to retain risk and to withstand the risk of cancellation due to highly unfavorable loss experience. Of course, the related policy question is whether these companies which do have unfavorable loss experience due to product "defects" should continue to be viable.

2.4.4 Alternative Risk Shifting

A widely used non-insurance method of risk shifting is a "hold-harmless" agreement. This is a contractual arrangement in which a manufacturer and a vendor define their relative responsibilities regarding claims from third parties--while the risk shifting can go in either direction, there is some benefit with the organization having the larger financial resources accepting more of the risk through such agreements. The organization accepting such risk is not protected from the additional liability risk through its product liability coverage but through other contractual liability insurance. This risk shifting between commercial organizations would generally be upheld unless one of the parties were forced to accept the risk because of the excessive use of market power by the other. However, in no circumstances could a manufacturer or vendor effectively shift the risk for a product "defect" to the consumer.

2.4.5 Product Liability Claims Survey

In 1976, the Insurance Services Office (ISO) initiated a Product Liability Closed Claims Survey (2-24) to compile a large experience base of product liability claims data. The program reviewed 24,452 claims closed by 23 insurers between July 1, 1976 and March 15, 1977. While claims relating to automobile parts and products were only a small portion of the total, the survey results for automobile parts and products (which are more fully described in Appendix B-8) emphasize the concern which might be expressed by manufacturers and vendors of EHV's and their insurers.

2.4.6 The EHV and Product Liability Risk

The structure of product liability law and the increased awareness of consumers has created additional risk in recent years for manufacturers and sellers. This is especially true for a consumer durable product such as the automobile. Product liability insurance or risk shifting is therefore necessary for those preparing to introduce the EHV to the consumer market.

However, in addition ro the above factors, three additional EHV factors were considered as either increasing or decreasing the ability to shift risk. The three factors are:

1. EHV Industry
2. Battery Power
3. EHV Performance

(2-24) Insurance Services Office Product Liability Closed Claim Survey: A Technical Analysis of Survey Results, Insurance Services Office (1977).

2.4.6.1 EHV Industry

Participants in the EHV industry are typically small organizations, with limited resources and limited experience in manufacturing a high volume consumer durable product. Such organizations may not have the capacity to develop loss control techniques such as manufacturing standards, advanced inspection and testing procedures or to provide safety design and engineering unique to the EHV. The result to be expected is either higher rates for product liability insurance or limitations in the coverage, at least until favorable product experience is noted. Discussions with participants (2-25) in the Department of Energy Demonstration Program noted the availability of liability coverage but limitations for some manufacturers in not being provided assurance of coverage for the projected life of the EHV or cancellation with a short notice time provision. Similarly vendors noted resistance from their own insurers in that the manufacturer had less financial resources than the vendor and the vendor might become the "deep pocket" from whom an injured consumer would seek recovery.

2.4.6.2 Battery Power

The unique aspects of a battery powered automobile were not specifically evaluated in relation to a product liability hazard other than to note two areas of risk: explosion risk of potential hydrogen accumulation and acid risk. While experience with the wet cell battery and its role in an ICEV is considerably different than the wet cell battery role and design will be in the EHV, contact was made with the Consumer Product Safety Commission's Electronic Injury Surveillance System and with the National Society to Prevent Blindness to identify injuries associated with wet cell batteries. The results are estimated injuries based on injuries reported by 119 hospital emergency rooms participating in the system. The estimates for 1975 through 1978 were:

TABLE 2-4 ESTIMATED INJURIES FROM WET CELL BATTERIES (2-26)

Injury	1975	1976	1977	1978
Eyes	2,857	5,307	5,165	6,459
Total, all body parts	3,930	6,875	8,275	8,167
Total, all body parts additional injuries from batteries, type not specified but majority assumed to be related to wet cell batteries	6,286	6,422	7,524	6,875

(2-25) Private communications.

(2-26) Letter communication, National Society to Prevent Blindness to Allan S. Bufferd, August 31, 1979.

Reports of the National Injury Information Clearinghouse of the Consumer Product Safety Commission indicate that these accidents are not solely the result of attempts to "jump start" ICEV's with battery cables. Some occurred on opening a hood, filling with water, dropping the battery, etc.

There are therefore some unknown product hazards to be anticipated with the increased number of wet cell batteries in EHV's and in the service and supporting structure for recharging, repair and maintenance.

2.4.6.3 EHV Performance

The performance characteristics of EHV's include limited speed and lower acceleration capacity than ICEV's. One might consider whether the sale of such EHV's to consumers is the sale of a product with a "design defect," if the experiences and expectations of the average driver, without special training or without sufficient warnings, are as they are now. Under circumstances where such limited speed or lower acceleration capacity were directly related to physical harm incurred, a "design defect" determination might be made. One might note the insurance company comment (Section 2.2.3):

"The lack of safety power for crash avoidance is a detriment."

The added product liability risk is therefore considered to be that risk which results from the performance capacity of the EHV being considered a "design defect", if the EHV is sold to consumers for use as a private passenger automobile.

There are both needs and difficulties for the EHV industry to secure appropriate product liability risk protection which might be alleviated by the Federal government. A discussion of those alternatives to provide appropriate risk protection are presented in Chapter 4 of this study.

3. ANALYSIS OF THE INFRASTRUCTURE FOR RECHARGING ELECTRIC VEHICLES*

3.1 SUMMARY

The mobility of the existing personal-vehicle fleet is provided by a refueling infrastructure consisting of petroleum refiners, distributors, and service stations. This chapter identifies the equivalent infrastructure that would be required to support a fleet of electric vehicles (EV), and analyzes the current status in the United States of its major components. The components include the electric utility companies, the types of dwellings at which it would be practical to recharge electric vehicles overnight, and methods for providing range extension, i.e., additional vehicle range without overnight recharging.

Many of these elements are already in place. The U.S. utility industry has sufficient capacity to support at least 13 million EVs, if they are recharged at night. There are at least 20 million single-family homes where it would be possible to recharge an EV by adding a branch circuit and outlet with a rating of 230 volts at 50 amperes. This support is not uniformly distributed, however, and will depend strongly on the characteristics of the local housing stock.

However, even with these elements in place, EVs are still range-limited and mobility is therefore still not equivalent to that of the existing personal-vehicle fleet. EV parity in mobility can be achieved only through range extension support, a major element of the refueling infrastructure for EVs that is currently missing. Three alternatives are examined: (1) transient recharging stations, where the EV is recharged while the owner is at work, shopping, etc.; (2) battery swapping stations, which replace discharged with fully charged batteries; and (3) hybrid vehicles, which have a small internal combustion engine (ICE) in addition to the electric engine, for range extension.

It is shown that all three would extend EV range to that of an ICE vehicle. However, transient recharge stations, while of value for emergency recharging, would not be desirable for daily use. Battery exchange would be a feasible alternative once there were enough EVs on the road to support a battery leasing operation and a network of exchange stations. The range extension hybrid is a solution that would be able to utilize the existing ICE refueling infrastructure,

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but would require further technical development, and would still depend, to a limited extent, on the availability of petroleum.

3.2 INTRODUCTION

The mobility of the current fleet of personal-transportation vehicles depends on the existence and continued operation of the petroleum industry. The infrastructure of this industry includes a myriad of operations involved in recovering petroleum from the ground, transporting it to refineries for conversion into automotive fuels, distribution to service stations, and sale to the ultimate customer--the driver of an internal-combustion-engine (ICE) vehicle. Disruption of this infrastructure would rapidly lead to the total immobility of ICE vehicles, with catastrophic effects in the industrially advanced countries whose transportation systems depend largely on the operation of ICE vehicles.

One of the advantages foreseen for electric vehicles (EVs) is that they do not in general require liquid petroleum for their operation. In most regions of the U.S., even today, no petroleum is used to generate electricity during off-peak periods, and in the future electricity will increasingly be generated from a number of other sources of energy. Hence, using electric vehicles to provide a significant portion of personal mobility would result in significant reductions in national dependence on petroleum.

Implicit in the development of a major fleet of over-the-road electric vehicles is the existence, or parallel development, of an infrastructure that will provide the vehicles with electrical energy. The object of this chapter is to: (1) identify the key institutional elements of the EV refueling infrastructure, (2) analyze the important subelements and options, and (3) establish the size of the EV fleet that could be supported in the United States, given the current and projected status of these institutional elements.

3.2.1 Definition of an Infrastructure for Recharging Electric Vehicles

Figure 3-1 represents the functional steps in providing electricity to an EV. The steps in the first row include the generation of electricity and its transmission to the site where it will be used to recharge the EV battery. These are functions of the electric utility company. The second row consists of the electricity distribution system on the property where the EV battery is being recharged, from the "head of service" (i.e., the utility interface) to the electrical outlet for the battery charger. The third row consists of the components required to modify the electrical energy and store it in the EV's

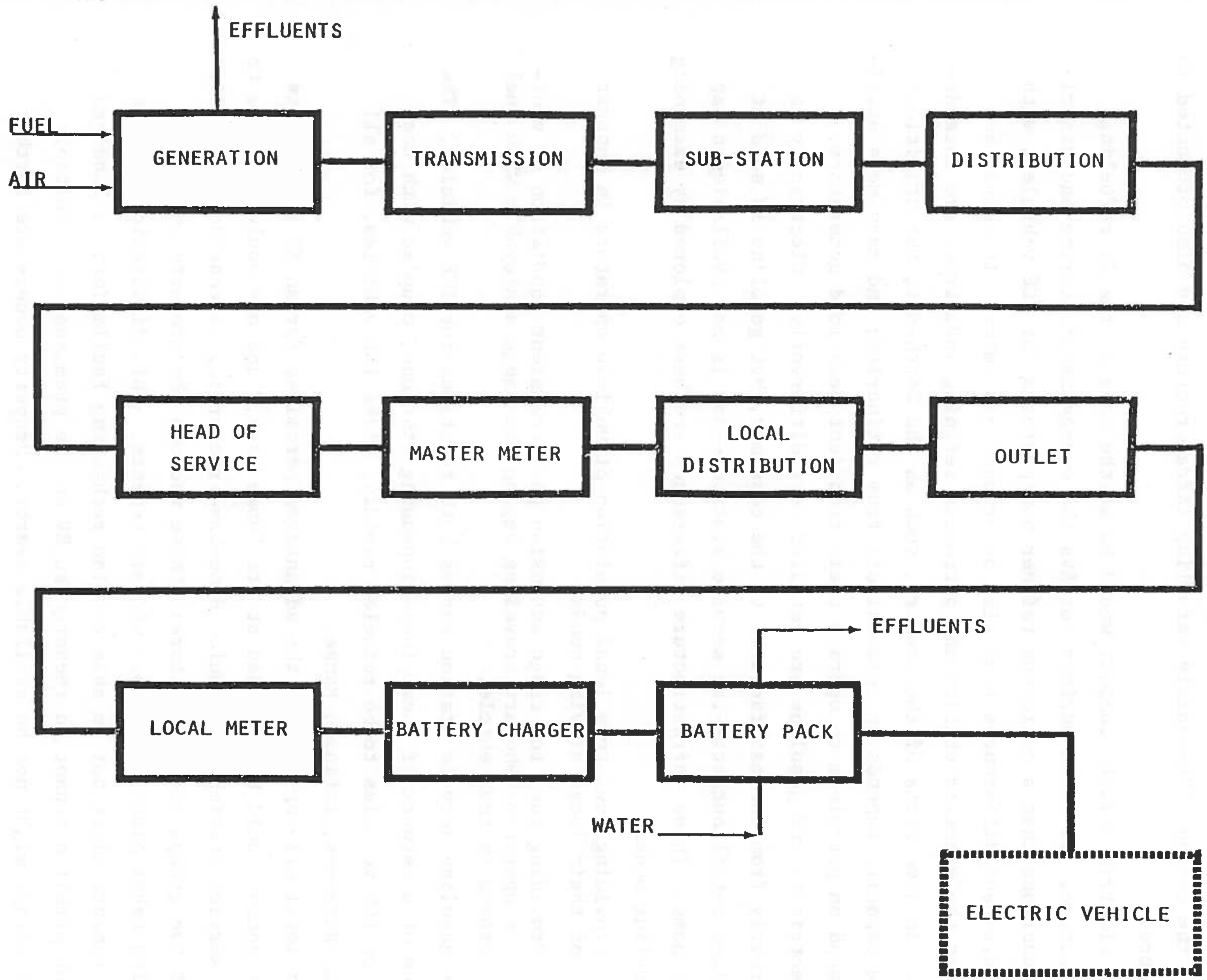

FIGURE 3-1. ELECTRIC VEHICLE RECHARGING SYSTEM FLOW DIAGRAM

batteries. The elements in the third row could be either on or off the EV.

The institutional elements of an EV recharging infrastructure which would satisfy these functional requirements are outlined in Figure 3-2. The key elements of the current ICE-vehicle refueling infrastructure are also presented in this figure.

The electric utility company would be at the apex of the EV refueling infrastructure. It would perform for EVs the energy manufacturing and distribution functions that a petroleum refiner now performs for ICE vehicles, with some significant differences that will be brought out later. It should be noted that the electric utility and petroleum refining industries are interdependent. In some parts of the country, such as the Northeast, the utilities' baseload capacity depends on residual oil from refineries; and many more utilities depend on petroleum to operate their transient peak-load generators.

Electricity and gasoline are retailed very differently. Electricity is sold directly from the manufacturer to the consumer, but gasoline is sold at specialized retail outlets--the service stations--and is not available on tap at one's home. These infrastructure differences are best explored by examining two refueling modes:

1. Providing fuel to a local population of vehicle operators in support of their local driving needs.
2. Providing fuel for range extension to a transient population of vehicle operators who are traveling beyond the range achievable with fuel stored in the vehicle.

The gasoline service station serves both functions for ICE vehicles. The existence of a network of local fuel-dispensing stations, coupled with the ability of ICE vehicles to be refueled rapidly, gives ICE vehicles, for all practical purposes, infinite range.

For local driving, one of the advantages perceived for an EV is that its electric energy could be provided at its "home base," and one would not have to go to a service station to refuel. Home-base recharging is considered here in terms of two groups of EV operators: those who own the property on which recharging takes place, and those who are tenants. This distinction is made because tenants might not be able to find recharging facilities: a landlord might not permit a tenant to recharge an EV on the premises, or a suitably equipped garage might not be available nearby. Property owners are further divided between private individuals and commercial or institutional owners, to examine (1) the differences in the number the type of EVs that would be

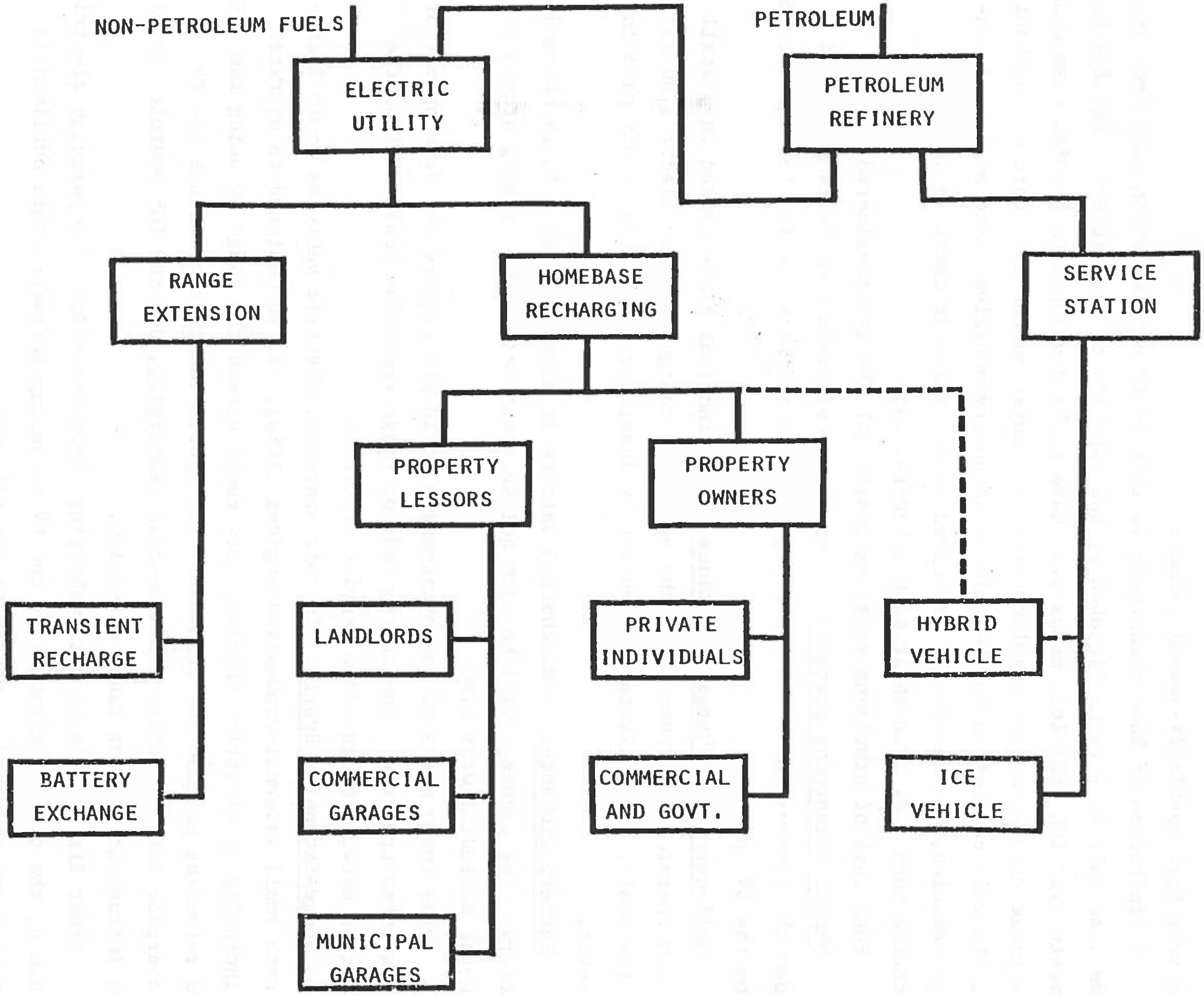

FIGURE 3-2. COMPARISON OF VEHICLE REFUELING INFRASTRUCTURES

recharged at one location, and (2) the differences in electricity rate structures offered to individuals and commercial firms. Likewise, rented facilities are divided into those rented from residential landlords, commercial garages, and municipal (publicly-owned) garages.

A limitation of home recharging is that an EV can be driven away from its home base only to a range dictated by the capacity of its battery. For EVs to compete with ICE vehicles, means will have to be developed to provide them with the range extension that gasoline stations confer on the ICE vehicle. Without it, EVs will be limited to the role of secondary vehicles. And even as secondary vehicles, EVs may not be perceived as desirable if there is no way to recharge them away from their base of operations.

Four ways of providing range extension for EVs are considered:

Manned recharging stations. A transient electric vehicle is recharged under the supervision of an operator, who also collects the fee for the service from the EV operator.

Self-service recharging stations. The transient EV is parked in a stall by its operator, who then plugs the vehicle's charger into an electric outlet in the stall, and activates the outlet by inserting coins or a credit card into a meter.

Battery exchange. A discharged battery is exchanged for a fully charged battery. The exchange will be much quicker than recharging, taking around 5 minutes excluding wait time.

These three modes of range extension would all require the development of a new infrastructure. The fourth mode of range extension would utilize the existing network of gasoline service stations:

Range-Extension Hybrid. In this approach, electric vehicles would incorporate small internal-combustion engines (ICEs). While designed to operate principally as electric vehicles, they could extend the range by using the ICE and refueling at gasoline stations. The hybrid vehicles would use the EV recharging infrastructure for home-base recharging, and the ICE vehicle refueling infrastructure for range extension.

After first defining the recharging characteristics of a paradigm electric vehicle, the various elements of the EV refueling infrastructure outlined in Figure 2 are examined to determint the following:

- The size of an EV fleet that could be supported by US electric utility companies, based on their present and projected capacity.

- o The number of housing units in the US where basic facilities that would be required for EV recharging are available or could be installed, and an estimate of the cost of installing the needed electrical circuitry.
- o The relative merits and costs of the range-extension options.

3.3 RECHARGING OF A PARADIGM VEHICLE

For the purposes of the present analysis, it was assumed that an average future electric vehicle can be characterized by the present Department of Energy objectives for the Near Term Electric Vehicle Program (3-1). These objectives include a range of 75 miles (121 km) between recharges; a specific energy consumption of 0.5 kWh/mi (1.12 MJ/km) at the outlet; and a re-charge time of 6 hours or less. Based on a projected utilization of 10,000 mi/year (16,000 km/year), an average EV would consume 5,000 kWh/year), an average EV would consume 5,000 kWh/year of electrical energy. This is comparable to the average annual electricity use by residential customers in the US, which was 8,430 kWh in 1978 (3-2). If the EV is used 250 days per year (the approximate number of working days), the projected utilization corresponds to 40 mi (62 km) on an average day, with an electrical energy requirement of 20 kWh. If the vehicle were to be driven to its maximum range of 75 mi (121 km), 37.5 kWh would be required to fully recharge the battery.

EV rechargers will have to be compatible with electricity supplied to single-family homes (either 115 volt or 230 volt single-phase AC), and with the provisions of building codes that establish standards for electrical circuits in single-unit residences. Most municipal building codes are based on the National Electric Code of the National Fire Protection Association (3-3). While this code has no provisions for the recharging of EVs, it does give standards for the maximum rating of plug-in appliances, which presumably would apply to EVs. The maximum power than an EV charger will be able to draw can be calculated by examining these standards.

(3-1) "Electric and Hybrid Vehicle Program," 2nd Annual Report to Congress for Fiscal Year 1978, US Department of Energy, January 1979, p. 24.

(3-2) Statistical Yearbook of the Electric Utility Indusry for 1978, Edison Electric Institute, November 1979. Table 46S, p. 54.

(3-3) National Electrical Code--1978, National Fire Protection Association Report 70-1978, 1979.

The code presently allows an air conditioner with a rating of no more than 40 amperes and 250 volts single-phase to be connected by a cord and plug to a branch circuit where no other loads are applied, with at least 25-percent safety factor (i.e., a 50-ampere circuit). A 40-ampere, 230-volt battery charger would draw 9.2 kW of power from such a 50-ampere circuit. Alternatively, the maximum current allowed for a plug-in appliance connected to a branch circuit with two or more outlets is 24 amperes, with a 30-ampere-rated receptacle being required. On a 115-volt circuit, this corresponds to a maximum power rating of 2.8 kW.

The total overnight recharge cost can now be calculated by examining the rate of electrical energy transfer into a depleted battery, which is a function of the battery's state of discharge. The output of the charger has to be managed so as to promote the desired electrochemical reaction, with minimal side reactions such as the hydrolysis of the electrolyte and gas formation. In an idealized case, the current accepted by a battery decreases exponentially with time. In practice, while many different recharging modes can be used (3-4, 3-5), battery charging is usually done in three stages: an initial stage in which the current is limited to an acceptable value; a second stage in which the current drops with time as the state of charge of the battery increases; and a final stage in which a trickle current is applied to level the charge among the cells in the battery. Even though little energy is transferred during this third stage, it requires a long time (typically 3 to 4 hours).

Assuming an initial maximum current of 40 amperes at 230 volts (9.2 kW maximum power) for one hour, followed by a decay to the trickle-current level in 1.5 hours, and a 4-ampere trickle current for 3.5 hours, it would be possible to transfer 20 kWh of electrical energy in 6 hours, although occasionally, when the vehicle is driven to its maximum range of 75 mi (121 km), an additional two hours of maximum-rate charging would be required.

With the same charging profile, but a maximum power input of 2.8 kW (24 amperes at 115 volts), only 9.6 kWh would have been transferred during 6 hours. This would only be sufficient energy to drive the EV 19.2 mi (30.7 km). An

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(3-4) J. Weiniger and F. Siwek, "A System Evaluation of Lead-Acid Battery Chargers," 4th International Electrical Vehicle Symposium, Dusseldorf, W.G., Paper 4.le, February 1976.

(3-5) E. E. Moyer, "Charging Requirements of Automotive Propulsion-Type Batteries," Society of Automotive Engineers Paper No. 690130, 1969.

average daily recharge would require approximately 10 hours, and a full recharge 16 hours. Such long recharging times would keep an EV attached to its umbilical cord for most of its existence. Another drawback is that such long recharging times would force EVs to be recharged, at least in part, during periods of peak demand for electricity.

In the rest of this paper, it is therefore assumed that the typical EV would be recharged at 230 volts, and that it would have a maximum power requirement of 9.2 kW. On the average, recharging would require 6 hours and would consume 20 kWh of electrical energy. Occasionally recharging could require as much as 8 hours with an electricity consumption of 37.5 kWh.

3.4 ELECTRIC UTILITY EV RECHARGE CAPABILITY

3.4.1 General Characteristics of the Electric Utility Industry

There are a number of unique characteristics of the electric utility industry that will influence the availability and price of electricity for an EV fleet.

Electricity is supplied in the US by many separate utility systems that are each regulated and licensed monopolies. Licenses are issued by a Public Utility Commission (PUC), a government agency usually at the state level, that grants the utility the exclusive right to provide electricity to the public within a given geographical area. In exchange for this monopoly, an electric utility has the responsibility to provide electricity to any bona fide customer at an equitable price set by the PUC. The cost of electricity to the consumer is based on a rate structure that reflects all the costs of providing this service, including a reasonable return on the capital investment required to build and operate the electrical plant.

Utilities vary significantly in their operating characteristics. Each utility has a different combination of types of generating equipment, so that the utilization of specific energy sources, including petroleum, varies from utility to utility. Also, the cost of operating and maintaining transmission and distribution lines varies with the geographical, demographic, and regulatory characteristics of the region of operation.

The generating capacity of a utility is geared to reliably supply the peak demand of its customers. In order to assure reliable service, the generating capacity, including net purchases of electricity from other utilities, generally includes a 15 to 25 percent reserve capacity over projected peak demand.

The demand for electricity varies continuously, both on a diurnal and seasonal basis. It varies also with the customer mix of the utility. Utilities that mainly have residential and commercial customers experience a demand that peaks during the business day and is much less at night. Since electricity is used extensively for heating and air conditioning, there are seasonal and geographic variations in the diurnal demand for electricity. Utilities that have a high proportion of industrial customers that operate on a 24-hour basis experience less variation in daily demands.

Since the costs of generating electricity depend on the mode of operation of the utility, and are passed through to the customer, the price of electricity varies from utility to utility. A significant part of this price variation is due to differences in the costs of generating electricity, especially the costs of fuel, as shown in Table 3-1. Capital-related costs also contribute significantly to an electric bill. Utilities that have low generating costs, such as those in the Pacific Northwest where hydroelectric power is common, tend also to have low fixed costs because they serve large industrial users whose power demands are either constant or schedulable, so that the utility's generating plant is more fully utilized.

It will be further noted from Table 3-1 that the costs of new electrical plants, especially generating facilities, have increased dramatically in the past few years, so that the marginal cost of new facilities is much higher than the average cost of existing plants. As a result, additional uses of electricity that result in greater peak demand add to the average cost of generating

TABLE 3-1 - ECONOMICS OF ELECTRICITY SUPPLY IN THE US IN 1977 (3-6)

	Steam Power	Nuclear Power	Hydraulic Power	Other Power	Average Production Plant	Total System
Cost of Fuel, mills/kWh	13.79	2.93	-	26.82	11.3	
Total Operation & Maintenance Expenses, mills/kWh	15.75	5.58	2.00	33.13	15.9	19.8
Average Capital Investment of Total Installed Plant, $/kW	157	357	210	100	172	362
Average Capital Investment of New Plant Installed in 1977, $/kW	305	1100	-	266	452	711
Utilization Ratio, Percent	46.7	64.5	36.3	7.8	44.4	

(3-6) Statistics of Privately Owned Utilities in the United States--1977, Department of Energy Report DOE/EIA-0044(77), January 1979.

electricity. Conversely, additional uses of electricity that could be restricted to off-peak hours would decrease the average cost of generating electricity, since such loads would improve the utilization of existing equipment without requiring new capital expenditures.

It has become an element of national energy policy to eliminate the diurnal peaks and valleys that currently characterize the use patterns for electricity. Under the Public Utility Regulatory Policies Act (PURPA) of 1978, every utility has to consider available alternatives for load management in order to shift electricity consumption to off-peak hours.

3.4.2 Availability of the Electric Utility Industry to Support EVs

The ability of the electric utility industry to support a sizable fleet of electric vehicles will depend on the operational characteristics of each individual utility system and on whether EVs will be recharged on an unrestricted basis, or on a scheduled basis at night when demand for electricity is at its lowest. Support on an unrestricted basis will depend principally on the excess on-peak reserve capacity of the utility system. Only those systems with significantly higher reserves than those needed for reliable service will be able to provide this support without increasing capacity. The amount of support available on a scheduled basis will vary with the diurnal demand pattern of the utility, and will depend on the ratio of off-peak demand to system capacity.

Because of the expected variations among different utility systems, the ability of the US electric utility industry to support EVs was projected from an analysis of fifteen major utility systems. In 1978 these fifteen systems had a combined net dependable generating capacity (including net purchases) of 135.8 GW, or 23.4 percent of the total US production. These fifteen systems operate in different parts of the country, have very different operating characteristics, and are considered to be representative of the total US electric-power industry.*

Support for Unrestricted Recharging - The following assumptions were used to estimate the size of an EV fleet that a given utility could support during peak hours:

1. The utilities will not operate with a reserve capacity of less than 25

*Estimates are based on data provided by the utilities to the Department of Energy on FPC forms 12 for 1978 and 12-E-2 for 1979.

percent. The maximum demand the utility will be able to support is therefore equal to 80 percent of the net dependable capacity (including net purchases).

2. The generating capacity available for EV recharge will be the difference between the peak load without EVs and 80 percent of the utility's net dependable capacity (including net purchases).

3. EVs will be recharged at random times, so that the total power demand for EVs will be equal to the number of EVs times the time average power demand of the paradigm EV, 3.3 kW (20 kWh/6 hr.).

Based on the net generating capacity of each of the fifteen utilities in the sample, it was estimated that their combined 1978 excess reserve capacity would have been sufficient to support a fleet of 1.5 million EVs charging during peak hours. (It should be emphasized that this is a lower-bound estimate; since it is based on a maximum-day demand, greater generating capacity would be available for most of the year.) This is equivalent to 6.4 million EVs in the US as a whole, since the sample represented 23.4 percent of the US generating capacity.

The support capacity varied widely, however. The available capacity was zero for nine of the utilities, less than 5 percent for four utilities, and more than 10 percent for the remaining two. These last two utilities, which had 22 percent of the generating capacity of the sample, accounted for 75 percent of the excess capacity on which the EV fleet calculations were made.

Since the major impetus for the development of EVs as a mode of personal transportation is conservation of petroleum, an argument can be made against recharging EVs with electricity generated by gas turbines and internal combustion engines. If the generating capacity of these units is discounted from the total generating capacity used above, thirteen of the fifteen utilities examined would have had no excess capacity available. The other two would have had sufficient excess capacity to support 650,000 EVs between them. These data do not allow a good estimate of the size of the EV fleet that could be supported across the US on this basis. They do indicate that most utilities would not be able to provide unrestricted support of EVs without using their peaking units on maximum demand days.

It is anticipated that the reserve capacity of the electric utilities will be lower in the late 1980s than it was in 1978. For 1988, most of the utilities in the sample examined are forecasting a reserve capacity, including peaking units, of 25 percent or less over maximum peak load (which does not include

EVs). This indicates that there will be little excess reserve capacity at the time EVs may be expected to emerge into the marketplace. In order to support the unrestricted recharging of EVs at that time, most utility companies would have to expand their generating capacity more than currently anticipated. Such an expansion of capacity would result in higher costs for electricity, which would further deter EV development.

Support for Off-Peak Recharging - The following assumptions were used to estimate the size of an EV fleet that a given utility could support during off-peak hours:

1. EV recharging is limited to those eight hours of the day when utility demand is at a minimum.
2. A utility will not operate peaking units during this time; all demand and reserve capacity are based on base-load generating capacity.
3. Available capacity for EV recharge is the difference between 80 percent of the net capacity excluding petroleum-based units and the maximum demand observed during any daily eight-hour minimum demand period given in Schedule 15 of FPC form 12. This assumes that the petroleum-based units will not be used even as reserve, and will provide a lower-bound estimate of available capacity.
4. The number of EVs that the utility can support is obtained by dividing the available capacity defined above by the paradigm vehicle's maximum demand of 9.2 kW. This assumes that all EVs in a given area would be recharged at the same time.*

The total power available for overnight recharging of EVs by the fifteen utilities was 28.1 GW, or 23 percent of their combined net base-load capacity. It is estimated that these fifteen utilities could have supported the off-peak recharge of about 3.1 million EVs in 1978. Extrapolating these results to the total US electric utility industry, it is estimated that 13.3 million EVs could have been recharged in the US with existing generating equipment on an overnight basis.

The ratio of the maximum off-peak demand to the net base-load system capacity varied from 0 to 32 percent among the utilities examined. One utility had no available off-peak capacity, and would not have been able to support the recharging of any EVs on an overnight basis. Four utility systems had an available off-peak capacity that was less than 10 percent of their net base-

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*This is a very strict requirement that gives a lower-bound estimate of the utility's support capability. More EVs could be supported if recharging were staggered over a wider time interval.

load capacity, six had more than 10 percent but less than 25 percent, and four had 25 percent or more available.

If the present usage patterns continue, off-peak capacity will increase as the total system capacity increases. With an expected annual growth rate of 3 to 4 percent in utility generating capacity (3-7) by 1988, the electric utility industry in the US would be able to support the overnight recharging of 18 to 20 million EVs. It is to be noted that the off-peak capacity that will actually be available may be significantly lower because of the greater emphasis on load management by the electric utilities and the public utility commissions. Thermal energy storage projects for space heating, water heating, and air conditioning, which are all under serious development, represent competitors to EVs for the off-peak generating capacity that will be available in the coming decade.

In summary, the availability of electrical power for overnight recharging of EVs will not represent an obstacle to the growth of a significant fleet of EVs in the US, but this power may not be available in all areas. However, there will be essentially no on-peak capacity available on maximum demand days. New on-peak demand will require greater use of oil-based peaking units or expensive capital investments, and will be contrary to DOE's load-leveling objective. Hence on-peak recharging should be avoided.

3.5 AVAILABILITY OF HOME-BASE RECHARGING FACILITIES

The purpose of this analysis was to define the characteristics of the potential EV operator and to assess whether the availability of "home-base recharging" facilities for EVs would present a problem to the introduction of EVs. The requirements for overnight recharging facilities were considered to include:

- Availability of off-street parking
- Access to electrical service
- Unused electrical service capacity of at least 50 amperes at 230 volts per EV during the charging cycle
- A branch circuit with a capacity of at least 50 amperes at 230 volts for each EV to be recharged
- An area where EVs can be recharged safely

(3-7) "Little Forecasts 4.1% kWh Growth to 1990," Electric Light and Power, 57(1), January 1979.

The first two requirements are obvious: it is necessary for the EV operator to have direct access to both land and electric power. This question of access divides potential EV operators into owners and lessees (tenants) of the property on which it is proposed to recharge the electric vehicle.

EV operators who are owners of property can be further classified as either businesses and institutions, or individuals, as previously mentioned.

Given access to parking and electricity, a further consideration is the quality of the available electrical service and the space provided for the recharging operation. The electrical service has to be large enough to accommodate the peak power drawn by the EV during charging (9.2 kW for the paradigm EV). To meet code requirements, the branch service to which the EV charger is connected has to have a minimum rating of 50 amperes at 230 volts. Service entry lines, panels, and fuses must all be large enough to accommodate this load in addition to any other electrical demands of the facility where the EV is being recharged. As regards the other characteristics of the EV recharging area, the major issue is safety, particularly adequate ventilation to ensure against the accumulation of explosive mixtures of hydrogen and air that can be formed during the charging.

3.5.1 Potential Private EV Owners

Characteristics of US housing and population published in the 1976 edition of the Annual Housing Survey of the US Bureau of the Census (3-8) were used to develop estimates of the number of households where the first three requirements listed above were met. Pertinent national data are presented in Table 3-2.

Characteristics of Housing - There is approximately one housing unit for every three inhabitants in the US, almost evenly divided between central cities, suburbs, and regions outside the Standard Metropolitan Statistical Areas (SMSAs). Most of the housing units are in one-unit structures (67 percent of all year-round housing units), and only 15 percent of all housing units are in structures that contain five or more housing units. While the concentration of one-unit structures is highest outside the SMSAs and in the SMSA suburbs, approximately 50 percent of the housing units in the SMSA central cities are in one-unit structures.

(3-8) Current Housing Reports, US Department of Commerce, Bureau of the Census, H-171-76, Summary of Housing Characteristics for Selected Metropolitan Areas, Annual Housing Survey: 1976, Supplementary Report No. 1, US Department of Housing and Urban Development, Sponsor, US Government Printing Office, 1979.

TABLE 3-2. PERTINENT DATA FROM THE 1976 ANNUAL HOUSING SURVEY

	U.S. OVERALL		INSIDE SMSA'S		SMSA CENTER CITIES		SMSA SUBURBS		OUTSIDE SMSA'S	
	Owner Occupied	Renter Occupied	Owner Occupied	Renter Occupied	Owner Occupied	Renter Occupied	Owner Occupied	Renter Occupied	Owner Occupied	Renter Occupied
Year Round Housing Units	79,316,000		53,606,000		24,547,000		29,059,000		25,710,000	
In 1 Unit Structures (%)	67.6		61.9		49.8		72.1		79.5	
In 5 or More Unit Structures(%)	15.0		20.1		28.0		13.3		4.4	
Occupied Housing Units	47,904,000	26,100,000	30,895,000	19,557,000	11,349,000	11,581,000	19,546,000	7,976,000	17,009,000	6,544,000
Above, as % Year Round Housing Units	60.4	32.9	57.6	36.5	46.2	47.2	67.3	27.4	66.2	25.5
Electricity Use										
To Heat House, % of Occupied Units	11.6	16.4	9.0	16.9	7.0	14.8	10.1	20.0	17.1	14.9
As Cooking Fuel, % of Occupied Units	55.7	38.1	52.9	34.7	44.8	27.9	57.6	44.9	61.8	49.2
Parking Owner Occupied Housed with Garage or Carport on Property, % of Occupied Units in Class	75.5		78.0		75.6		79.4		70.0	
Parking Included in Rental, % of Occupied Units in Class		91.5		92.9		93.2		92.5		86.8
Automobiles Available										
One (in % of occupied units in Class)	44.1	50.7	40.9	49.5	44.4	44.8	38.9	56.5	50.8	54.3
Two or More	48.1	19.8	52.1	19.5	45.0	14.8	56.2	26.4	39.3	20.9
Trucks Available	24.9	10.1	20.8	7.5	18.5	5.4	22.1	10.7	31.7	18.5

Source: Reference 3-8

There are approximately twice as many owner-occupied as renter-occupied housing units in the US as a whole. This ratio is about two-and-one-half for the SMSA suburbs and the regions outside SMSAs, but only about one for the SMSA central cities. Approximately 45 percent of the renter-occupied units are in the SMSA central cities, whereas 80 percent of the owner-occupied housing units are outside the SMSA central cities.

Capacity of Electrical Service - The minimum service for new family dwellings promulgated by the National Electrical Code of the NFPA is 100-ampere three-wire (230-volt) service for a dwelling with six or more two-wire branch circuits, or with an initial computed load of 10 kW or more. This service would be sufficient for an average household which uses an electric range and a typical complement of appliances but is not electrically heated. Modern "all-electric" houses have 150-ampere or 200-ampere three-wire service. According to utility company sources, the electric service of many older houses (built before 1960) has been upgraded to the 100-ampere standard for new construction.

A dwelling equipped with a 100-ampere three-wire service has sufficient panel capacity to support the recharging of an electric vehicle, and an equivalent combined electrical load from other household demands. This should be more than ample, as long as other high-load appliances are not used simultaneously. It would not be possible to meet continuous electrical demands (lighting, refrigeration, furnace operation), cook on an electric range, and recharge an EV simultaneously, but it would be possible to meet any two of these three loads at the same time.

In the absence of more specific data on the characteristics of electric service supplied to individual dwelling units and on their demand for electricity, the presence of an electric range was used as an indicator that the existing electric service had sufficient capacity to support the recharging of an electric vehicle. An electric range draws approximately the same amount of power as an electric vehicle. Any single-unit dwelling that has an electric range, therefore, has sufficient capacity to recharge an electric vehicle during off-peak hours when the range is not in use.

Referring to Table 3-2, at least 55 percent (about 26 million units) of the owner-occupied housing units in the US have an electric service of sufficient capacity to support the off-peak recharging of an electric vehicle; the figure is 45 percent in the SMSA central cities and higher in the SMSA suburbs and outside SMSAs. It is quite possible that a much larger fraction of owner-occupied dwellings have an entrance service of sufficient capacity, but substantiating data were not available.

The availability of adequate electric service for EV recharge in multi-unit dwellings with parking garages was not specifically analysed. Given the electricity requirements of such facilities, as compared to a one-unit dwelling, it is presumed that the entrance service facilities on a per-unit basis should be ample to support the recharging of a limited number of electric vehicles during off-peak hours.

For the renter-occupied housing units, the electric-range criterion can be used, but on a more constrained basis than for the owner-occupied dwellings. The projected maximum demand load specified by the National Electrical Code does not increase proportionately with the number of electric ranges in a dwelling, because a lower demand factor is applied to each additional appliance: 8 kW for the first, 3 kW for every unit above 40. Based solely on the use of electricity for cooking, the above indicates that the larger the building, the smaller the number of EVs that could be recharged off-peak per electric range in the building. It is estimated that the service capacity would be sufficient to recharge 1 EV per unit in a one-unit dwelling, 0.5 EV per unit in a three-unit building, and 0.22 EV per unit in a 20-unit building.

According to Table 3-2, 38 percent (10 million) of the renter-occupied housing units use electricity for cooking. Because of the large proportion of rental units in multiple-unit dwellings, it is estimated that the electricity service to rental units could support at least 4 to 5 million EVs on a national basis. It is to be further noted that the percentage of units in structures with five or more units is nearly twice as high in the SMSA central cities as it is nationally, and only 27.9 percent of rental units in SMSA central cities use electricity for cooking as compared to 38.1 percent for renters on a national basis. As a consequence, it is estimated that electricity service to renter-occupied dwellings in SMSA central cities would be sufficient to support only about 1.3 million EVs, even though 44 percent of the renter-occupied housing units are in SMSA central cities.

Availability of Off-Street Parking - Another required element for EV recharge is the availability of off-street parking. As indicated in Table 3-2, over 75 percent of the housing units in the US have a garage or carport, a value that understates the number of owner-occupied housing units with off-street parking facilities, since it does not include uncovered off-street parking. Parking is available at over 90 percent of the renter-occupied units in the country. There is little difference, surprisingly, between the availability of off-street parking in SMSAs and in regions outside SMSAs.

Estimate of Number of Units with Basic EV Recharge Facilities - A lower-bound estimate of the number of housing units that have the basic requirements for EV recharge is obtained by multiplying the number of housing units by the percentage of units that have a sufficient electricity supply, and by the percentage of units that have off-street parking. The results for owner-, renter- and total occupied housing units are presented in Table 3-3. It is estimated that there were 25 million housing units in the US in 1976 where EVs could have been recharged, with the installation of a suitable branch circuit and the provision of adequate ventilation. The great majority of these units are owner-occupied. About ten million of the units are in the SMSA suburbs and ten million in regions outside the SMSAs. Only five million housing units

TABLE 3-3 ESTIMATED NUMBER OF HOUSING UNITS IN US IN 1976 WITH BASIC EV RECHARGING FACILITIES

	Owner Occupied Units	Renter Occupied Units	Total Occupied Units
	Number of Housing Units, Millions		
U.S. Overall	20.2	4.4	24.6
Inside SMSA's	12.8	2.0	14.8
SMSA Center Cities	3.8	1.2	5.0
SMSA Suburbs	9.0	0.8	9.8
Outside SMSA's	7.4	2.4	9.8

within the SMSA central cities would have had adequate support facilities. Further analysis of individual SMSAs indicates significant variations in EV support capability. The inner cities of the very large SMSAs tend to be poor in this respect because of the preponderance of large multiple-unit rental buildings.

Cost of Providing Home Recharging Capability - In all cases, even if the basic recharge facilities were available, a separate branch circuit with a 50-ampere, 230-volt capacity would be required for every EV to be recharged. At a single family home, the cost of installing such a circuit would run from about \$200 to \$430 (3-9). If an EV were to be recharged in an enclosed garage, an interlocked fan would also be required, adding approximately \$100 to the

(3-9) W. Harshberger, "Installation Costs for Home Recharge of Electric Vehicles," RM 2291, General Research Corporation, Santa Barbara, CA, January 1980.

installation costs. Installing the required electric circuits in a multi-vehicle garage or parking lot typical of those associated with multi-family rental dwellings would be more expensive. It is estimated that a landlord would have to spend $350 to $650 per stall, depending on the number of stalls, whether they are open or covered, and whether they are located in old or new construction. In order to achieve a 20-percent pre-tax return on investment, and cover the fixed costs (28 percent of investment), the landlord would have to increase the parking fee to an EV owner by $15 to $35 per month.

EV Ownership by Renters - We believe that it will be very difficult for a renter to consider owning an EV. Not only do proportionately fewer rental units have the basic facilities required for EV recharging, but providing the necessary outlets for recharging will be more expensive for multi-vehicle parking areas than for a single-vehicle parking area. Property owners have direct access to their entrance electrical service, but renters do not. For EV recharging to be supported at renter-occupied units, the landlord will have to be in agreement. Unless and until EVs become fairly commonplace, landlords will have little incentive to provide such facilities.

The attitude of a commercial garage operator would not be expected to be significantly different from that of a landlord: recharging facilities would be installed only after a demand was created. It might not need as large a proportion of EVs to elicit a response from a commercial garage operation, because it could draw on a larger population than a given landlord. Municipal garages, which also have to take into account the social costs of on-street parking in congested areas, might be more receptive to providing recharging outlets for EVs, as a means of getting cars off the street at night.

The availability of recharge facilities for renters may be of little importance as long as a range-extension infrastructure for EVs is not in place. As noted in Table 3-2, less than 20 percent of the renter-occupied units have two or more cars available, as compared with nearly half the owner-occupied units. Counting trucks, it was calculated from the data in Table 3-2 that the average owner-occupied housing unit in the US has access to 1.78 automotive vehicles, but the average renter-occupied unit has access to only 1.04 automotive vehicles. Without a range-extension infrastructure, EVs will be usable only for local driving and therefore their appeal will be mainly as second cars--a use that will have little appeal to most renters.

3.5.2 Potential Commercial (Fleet) EV Owners

Most commercial and institutional operators of motor vehicle fleets that would consider the purchase of EVs for part of their operations would have all the requisite facilities for EV recharge with the exception of the specific branch circuits to which the EV charger would be connected. Such operations are usually large entities that are equipped with a sizable entrance electric service--typically 150 kW or more. Since the electric bill of such operations is based on both peak demand and total consumption, it is unlikely that their EVs would be recharged except during off-peak periods. Branch circuits would have to be run from the entry panel to the recharging location. Installing the branch lines for a recharging facility would range from about $350 to $650 per vehicle. The enterprise would add these costs to the sales price of the EVs in deciding whether to replace ICE vehicles by EVs.

3.6 RANGE-EXTENSION FACILITIES

No range-extension facilities for EVs now exist, so that a complete infrastructure would have to be created. A rudimentary infrastructure of transient recharging stations existed along the eastern seaboard about sixty years ago, but has long been dismantled (3-10). Developing a new infrastructure may prove to be difficult.

One of the key advantages of EVs, their ability to be recharged at their home base, is also a major obstacle to the development of range-extension infrastructures. There is approximately one gasoline station for every 800 motor vehicles registered in the US (3-11). Most of these gasoline stations are supported by local customers, rather than by the travelers from afar for whom they provide range extension. The few gasoline stations that are supported by their range-extension business are those strategically located on major highways.

Applying this reasoning to EVs, it follows that even if many EVs were in operation, the number of range-extension facilities would be less than the number of petroleum service stations now required to support the same number of ICE vehicles. There may be a "critical mass" problem in the development of an EV range-extension infrastructure. The population of EVs may not grow to the level required to support a range-extension infrastructure without the prior

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(3-10) H. C. Cushing, Jr., and F. W. Smith, The Electric Vehicle Handbook, 2nd Edition, H. C. Cushing, New York, 1915.

(3-11) 1977 Census of Retail Trade, US Department of Commerce, 1979.

existence of the infrastructure.

The extended period of time required to recharge the battery of an EV is another factor that has to be taken into account in considering range-extension options for EVs. The hours required for recharge are not an obstacle to overnight recharging, but would not be acceptable to automobile travelers who are used to being able to refuel an ICE vehicle in a matter of minutes at a service station.

A third factor is that most of the demand for range extension would be expected to occur during the work day or early evening, i.e., at those times when electric utilities experience their greatest demand for electricity. Recharging during these hours would present a severe load management problem, particularly because of the large variation in power demand of the charger during the battery charging cycle.

These problems and others are considered below in a detailed examination of each of the range-extension modes outlined in Figure 3-2. Briefly, their salient advantages and disadvantages are as follows. Battery exchange allows for rapid "refueling," and would not require electricity during periods of peak demand. However, the development of a battery-exchange infrastructure would require that a substantial fraction of vehicles be EVs and could function only if batteries were leased by the exchange stations. Alternatively, transient recharging of an EV would be slow, require electricity during hours of peak demand, and be expensive as a result. The most attractive option for range extension is the hybrid vehicle, which could utilize the existing infrastructure of gasoline stations. However, this approach uses petroleum for range extension, and thus is a compromise which detracts from the principal purpose behind the development of EVs, petroleum conservation.

3.6.1 Range-Extension Hybrid

Aside from reducing the petroleum-conservation potential of an EV, the major disadvantage of a heat-engine battery-electric vehicle is its increased complexity and its possible attendant increased weight and cost as compared to either a pure ICE or an all-battery electric. However, with proper design balance of the dual-motive sources, it may be possible to arrive at a cost-effective hybrid vehicle that would retain the primary advantages of an all-battery EV, but have the unlimited range of an ICE vehicle when required.

A successful development program based upon the "range-extension" hybrid concept proposed by Hamiltion (3-12) would result in a vehicle that would satisfy these requirements. Such a range-extension hybrid would be basically an electric car modified by the addition of a small ICE and clutch. Its electric drive and battery pack would be sized to provide the required acceleration, rather than range. Hamilton estimated that the battery pack of a range-extension hybrid, with the same acceleration characteristics as an all-battery EV that meets DOE's near-term goals, could weigh 300 lb (140 kg) less than the battery pack of the all-battery EV. (This calculation is based on existing lead-acid batteries.) The small ICE that would be added should weigh, and cost, less than 300 lb of batteries, so that the hybrid vehicle should be lighter and less expensive than a comparable all-battery EV. The range of the hybrid would be comparable to that of an ICE vehicle. It is to be further noted that an advanced battery system would not be required in order to have a functionally effective range-extension hybrid.

The petroleum consumption of the proposed hybrid would depend significantly on its mode of operation, and on the relative prices of electricity and gasoline. If the price of gasoline were high compared to the price of electricity, the vehicle operator would have a strong economic incentive to operate mainly in an electric mode. Under these circumstances, the ICE might be used for 30 percent of all driving, or possibly less. Petroleum consumption would be proportionately less than that of an ICE vehicle in similar service, since the hybrid-ICE would have a smaller displacement and could operate at more constant speed.

If a range-extension hybrid could be built and sold for approximately the price established by DOE for an EV under its Near-Term EV Development Program (3-12), at current prices of gasoline (about $1.20 a gallon) and of electricity (about 4.5 cents/kWh), it would be more expensive to own and operate than a conventional subcompact automobile. However, such a hybrid would become competitive with the conventional car if petroleum fuel were taxed in the US at the rates currently prevailing in Western Europe. Under such circumstances, a range-extension hybrid would be a form of an electric car with real commercial potential that would offer most of the petroleum-conserving benefits of electrification.

3-12) W. H. Hamilton, The Potential of Range-Extension Hybrid Cars, RM-2263, General Research Corporation, Santa Barbara, CA, January 1980.

3.6.2 Battery Exchange

The concept of battery exchange was examined by Graver et al., of General Research Corp., under sub-contract to Argos Associates, Inc. (3-13) as a range extension adjunct to "home-base" recharging. This is a different approach from the one examined by the Transport and Road Research Laboratory in England, who considered battery exchange as the sole means of refueling and found it to be uneconomical (3-14).

This mode of "refueling" includes the exchange of a discharged battery for a fully charged one at a suitably equipped facility, enabling an EV to be effectively recharged or "refueled" as quickly as a conventional vehicle. The depleted battery would then be normally recharged during off-peak hours of electricity demand.

Swapping-station capacity was estimated as a function of service time and the number of service lanes, under the constraints that the average swapping time be 5 minutes, and that the probability of a 20-minute wait (including swap) be less than one percent. The average daily number of swaps for such stations, in a city and on a highway, were then estimated. Next, equipment and utility requirements, layout, staffing, and required battery inventory were determined. The costs of erecting and operating the swapping stations were then estimated, and the cost per swap to the EV operator derived by dividing total daily costs by expected station utilization.

If battery exchange is to be an adjunct to home-base recharging, then an EV operator will require the urban service only infrequently, approximately eight to thirty-three times a year for a 120-km vehicle (three to sixteen times for a 160-km vehicle), when additional range is required or when battery capacity or reliability become unsatisfactory. Swapping requirements depend on the EV's maximum range, with the number of swaps per year required for urban driving decreasing with increased vehicle range. However, as vehicle range increases, the demand for battery swapping for interurban travel would be expected to rise.

The number of EVs that a battery-swapping station can support depends on

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(3-13) C. A. Graver and L. Morecraft, "Electric Vehicle Range Extension: Battery Swapping Facilities," RM-2290, General Research Corporation, Santa Barbara, CA, March 1980.

(3-14) R. Weeks, A Refueling Infrastructure for Electric Cars, Transport and Road Research Laboratory Report 812, 1978.

vehicle range and number of swapping lanes. For example, a three-lane station, ranging in cost from $700,000 to $1,200,000 depending on location, can support about 4000 160-km EVs. A six-lane station (costing $1.4 to $2.3 million) could support over 10,000. For a 120-km EV, station capacities would be reduced by 40 percent as the number of urban swaps per EV will increase 1.7 times.

There is one major shopping center for approximately every 200,000 inhabitants in the US (3-15). In order to support a three-lane battery swap station in every major shopping center, about 3 to 9 percent of private automobiles would have to be EVs (of 120-km range). For a 160-km EV, the fraction would have to be 4 to 15 percent. The cost of battery swapping to an EV operator (excluding electricity) would range from $3 to $7 per swap, depending on the size of the station and the frequency of demand. Swapping would represent an additional cost to the 100-km EV's operator of $225 per year to $380 per year ($120 to $185 for the 160-km EV). While this additional cost is not considered to be especially burdensome, it still makes it that much more difficult for an EV to compete with an ICE vehicle on economic terms.

For a battery exchange system to function, EV battery packs will have to be standardized in dimensions and electrical characteristics. Automotive petroleum fuels are now sold in only a few standard grades, and it is anticipated that EVs will achieve the same degree of standardization in the future.

A further requirement for battery exchange to function is that the battery pack be leased from the swapping service. This would overcome the objection an individual might have to swapping a relatively new battery pack for one of questionable age and condition. Leasing of batteries will increase the life-cycle costs of vehicle ownership because of the administrative costs and profit requirements of the battery lessor. However, battery leasing would greatly reduce the first costs of EV ownership (to a level more comparable to that of a conventional automobile), since the battery pack would no longer be included in the vehicle's purchase price. Leasing would also transfer the risk of owning a defective battery pack from the EV operator to the battery lessor, who would spread the costs of this risk to all customers.

In summary, battery swapping, as an adjunct to battery leasing, would be a viable means of range extension for all-battery EVs that would be usually recharged at home. The development of a battery leasing infrastructure would

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(3-15) Santa Barbara County General Plan Report, Simon Eisner & Associates, 1965.

require the standardization of batteries and a 100-km EV "fleet penetration" of 2 to 6 percent.

3.6.3 Transient Recharge Stations

A transient recharge station would consist of a parking stall fitted with an electric outlet where an electric vehicle's charger could be plugged in. There are two approaches to transient recharging, manned and unmanned. At a manned recharging station, the driver of an EV would turn it over to an attendant, who would then supervise the recharging. When the driver returned to the station, he would be presented with a bill for parking and recharging, pay the cashier, and drive off. At an unmanned station, the driver would turn on the electricity by putting coins or a credit card into a meter. The concept is a derivative of the use of electrified parking meters that now exist in certain cities of the northern United States and Canada, where they are used to power heaters that keep the engine warm while the vehicle is parked in sub-zero weather. It has been claimed that if a large number of charging outlets were available in parking lots of supermarkets, office buildings, and factories (3-16), the short-range EVs that can now be made would be a viable model of personal transportation.

In considering the transient recharge of electric vehicles, the following must be taken into account:

- o The amount of power required and the energy flow characteristics
- o The design of the recharge facility and the required capital investment
- o The cost of electricity
- o The cost of transient recharge to the EV operator
- o The potential safety hazards and resulting liability

Battery Recharge Characteristics - Battery recharge involves a non-constant demand for electric current. For the paradigm vehicle, the initial power demand would be 9.2 kW if the EV had been driven 21 mi (34 km) or more, and only a tenth of that if it had been driven 6 mi (10 km). The energy that can be transferred into an EV in a given period of time depends significantly on the distance driven since its last recharge. Relatively little energy can be transferred per unit time into a vehicle that has been driven only a short distance.

(3-16) V. Wouk, "Another Way of Powering Vehicles," The New York Times, 12 July 1979.

Characteristics of the Recharge Facility - It was estimated by Harshberger, under sub-contract to Argos, that the capital investment for providing an electrical installation with the required rating of 50 amperes at 230 volts would range from $350 to $650 per stall, depending on the number of stalls, whether they were open or covered, and whether they were located in old or new construction (3-9) in an unmanned station, provisions would also be required for switching and metering electricity, measuring parking time, and receiving money (or its equivalent). Computerized central parking meters for unmanned lots are now available. For a 200-stall lot, such a system costs approximately $20,000 (3-17), which is significantly less than the cost of 200 separate mechanical meters. A similar system that would also control the sale of electricity in an unmanned recharge station would be expected to cost 20 to 30 percent more than the basic electronic parking system. For a 200-stall lot, the additional cost for circuit control would include $4000 to $6000, or $20 to $30 per stall, for the central computer, plus approximately $100 per stall for the individual control elements. With this approach, the total capital investment for the electrification of a public garage or parking lot would range from about $470 to $780 per stall.

Cost of electricity - A major element of the cost of transient recharge would be the cost of the electricity itself, particularly since it would be required at all times of the day. As a commercial user, the parking lot or garage operator would pay a "demand fee" based on the peak power demand, in addition to the "energy fee" per kWh used. Since it can be reasonably expected that all EV stalls in a recharging facility would be in use simultaneously at their maximum rating at least once during a monthly billing period, each outlet would add 9.2 kW to the peak demand. Demand fees at present range from $3 to $6 per kWh per month. They would rise to as much as $15 if new generating capacity had to be added and marginal unit pricing were applied.

The monthly energy fee paid by the recharging facility would depend on the average state of charge of the EVs using the facility, its mode of operation, and its average utilization. The energy fee would add between 66 cents and $1.09 to the cost per recharge (assuming a fee of 3.5 cents per kWh, and 30 km and 50 km average driving between recharges).

Cost of Recharging to EV Operator - The price for recharging would have to

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(3-17) A. Bugeau, Clareby Corporation, Westwood, Massachusetts, personal communication, 17 October 1979.

cover all the costs identified above: the cost of providing the facility, a return on the capital invested in the facility, and the demand and energy fees paid to the electric company. It is assumed here that a flat fee per recharge is collected, regardless of the amount of energy supplied. This policy would have to be applied by all recharging station operators who are not utilities and thus are not allowed by law in most states to resell electricity on a unit basis. This policy would be reasonable since the energy fee only represents a small part of the total costs. The required fee per recharge is estimated to range from $1.50 to $7.85, depending on the number of recharges per stall per day and the average amount of energy per recharge. A consequence of the above policy is that the electricity cost per kilometer rises sharply if the recharge station is used for "topping off."

Transient recharge will cost about the same as a battery swap. Recharging stations can be individually provided without a large infrastructure investment. However, the time necessary for a full recharge, and the use of on-peak power, make the alternative unattractive from both a convenience and institutional point of view.

Safety Hazards - An issue of concern is the presence of high-power electric outlets in unsupervised parking areas because of the potential hazard they represent. The electronic metering of electricity should eliminate many objections with regard to safety and vandalism that would exist with mechanical switching. With electronic control, all mechanical linkages with the high-power line are eliminated, other than the actual connection of the EV to the stall outlet. Interlocks can be placed in the circuit to permit safe activation of the circuit. However, even with these safeguards, there would still be a potential for accidents which raises many legal questions relating to liability. We consider that the potential for accidents and liability would be significantly reduced in manned recharging stations where trained operators would be performing the recharging function.

We conclude that it would be possible to justify the installation of a few recharge stalls in an area to serve as a lifeline service for EVs in distress, but not to consider the formation of an extensive network of "biberonnage" stations, as has been suggested in the literature (3-16). Such a network would not only be uneconomical, but detract from the petroleum-conservation potential of EVs and aggravate the load-management problems of the electric utilities.

4. POLICY ANALYSIS

4.1 SUMMARY

The objective of the study was to seek to determine if federal policy actions were needed to overcome institutional barriers to the use of battery powered vehicles on a National basis.

The largest institutional barrier identified appears to be the lack of a range extension infrastructure for electric vehicles. The next most important difficulty to EV use stems from the lack of a sufficient number of home base facilities for vehicle recharge. It was also concluded that serious insurance problems for EV operators do not exist, and that product liability insurance is available to manufacturers, albeit at a higher cost.

At this time, it does not appear that an "insurance" policy action is required for the benefit of the manufacturer or the consumer. First, electric vehicle owners appear to be able to obtain insurance for liability, property damage, and collision on essentially the same terms as owners of ICE vehicles. There should be an improvement in the accuracy of the insurance rates as the federal demonstration program moves forward and there are more electric vehicles on the road. With regard to product liability protection for the manufacturers, it appears that this insurance is available, but at a cost which may result in a higher selling price for an EHV. Because most electric vehicle manufacturers are relatively small companies with limited resources, distributors and retailers may be discouraged from participating in the sales of EV's and EHV's in the nearer term because of the product liability question. This should not be an issue for the demonstration program under which vehicles are purchased directly from the manufacturer. Operation of EV's under the demonstration program should yield an experience base which will provide a more precise evaluation of the product liability aspects of EV's. However, the impact of product liability considerations on the development of a retail dealer network should be reviewed near the end of the demonstration program. At that time, liability insurance subsidies may be deemed appropriate. However, by then, major auto manufacturers might be interested in electric and hybrid vehicles, and may have joined with the existing smaller manufacturers through acquisition, which would make the product liability issue moot.

The off-peak capacity of electric utilities, nationally is sufficient for over 13 million electric vehicles, but load management of vehicle recharge is mandatory. The Public Utility Regulatory Policies Act of 1978 already mandates consideration of all possible actions to optimize load management. Further federal action beyond this existing statute does not appear required as far as the recharging of EV's is concerned.

The discounted cost of mitigating the consumer perceived disadvantage stemming from installing home base recharging facilities, if applied over fifteen years until the rate of introduction of battery powered vehicles were 400,000 units per year, would cost between $18 million, at a 10% subsidy level, and $180 million, at a 100% subsidy level, and would apply to the installation of 1.7 million facilities. A twenty year program, which would apply to 8.2 million facilities, would cost between $51 million (10% subsidy) and $510 million (100% subsidy) on a discounted basis. Such action, by itself, would not be sufficient incentive to accelerate the sale of EHV's as long as operating costs of battery powered vehicles remain significantly greater than those of comparable ICE vehicles.

In the near term, as long as petroleum fuels are available, range extension through the development of a hybrid vehicle eliminates the problem of range extension infrastructure, permitting the use of existing gas stations, and can be implemented through continued funding of research and development of various types of hybrid vehicles. No action should be taken to develop a network of recharging stations except to provide tax credits, similar to those proposed for home base rechanging facilities for a very limited number of supervised recharging stations that could provide lifeline service for battery powered vehicles in distress. In the longer term, if and when hybrid vehicles will not be able to operate for lack of petroleum fuel, battery swapping could be a mode of providing range extension for all-battery vehicles. As a basis for incentives and cost estimates, it was assumed that incentive policies would reduce the total cost of energy per distance travelled for an EV to that of a fuel efficient ICE vehicle. The total cost of energy for an EV is the sum of the cost of electrical energy needed for propulsion plus the cost of storing this energy on board the vehicle. The latter term is the cost of the battery. The total cost of energy for an ICE vehicle is the cost of petroleum fuel consumed per distance travelled plus the cost of storing this fuel on board the vehicle. The latter term in the case of an ICE vehicle is negligible. A seventeen year subsidy program which would support the leasing of batteries for 2.3 million EV's, is outlined, which given current prices, technology, and trends, would cost the Government approximately $380 million, in 1979 discounted dollars. Such a subsidy program would not be effective over the initial years of introduction of EV's because a critical vehicle fleet size would not be attained. During this initial period, a government funded battery swap demonstration program, which would cost an estimated $50 million, might be a more effective tool for promoting this approach to range extension.

In summary, the total cost of the subsidy programs that were addressed in this study as tools to overcome the institutional biases against battery electric vehicles of the need for home base recharging and the absence of range extension facilities, could have a discounted cost of over $3.8 billion. This figure assumes 100% subsidy of the cost of home base recharging facilities and battery costs for 8.2 million EV's introduced during an initial 20 year period. If government subsidies were applied as a means of reducing the cost of operating an EV to that of an ICE vehicle, they would apply to the first 2.3 million EV's marketed over a seventeen year program, and would have a discounted cost of $460 million to $710 million, as outlined below:

Home Base Recharging:	$28 million to $280 million
Subsidy to Battery Lessors:	$380 million
Battery Swap Demonstration Program:	$ 50 million

4.2 SCOPE OF POLICY ANALYSIS ADDRESSED

The scope of policy options addressed in this study are limited to the consideration of those federal actions which could be taken to overcome the institutional barriers that were analyzed in depth in other sections of this report, consistent with the requirements of Public Law 94-413. Other paths than the use of EHV's to achieve petroleum conservation in the transportation sector, were not considered. Alternate policy options were considered for the three institutional barriers identified in this study as being likely obstacles to the growing use of electric vehicles:

- o Availability of adequate insurance coverage for the consumer (liability) and the manufacturer (product liability) at a cost competitive with the same protection afforded owners and manufacturers of ICE vehicles.
- o Availability of home base recharging facilities and electrical energy supply capacity to EV and EHV owners/operators.
- o Availability of range extension services, locally and on the highway.

Consideration was given to a variety of Federal Policy options that were thought would stimulate the market for electric cars by overcoming these perceived institutional barriers, and thereby achieving "parity" between an EV/EHV and an ICEV. Under this philosophy, federal actions would be taken to "equalize" the EV/EHV and the ICEV in terms ranging from cost to performance. These actions could possibly range from inaction to direct intervention in the form of subsidy or regulation. Specific government actions that were considered included regulation, tax credits, coinsurance, large scale purchases, and the financial support of research.

In order to provide a basis for the potential costs of different policy options being considered, it was necessary to make some assumptions as to the future growth in the number of battery powered vehicles that would be in operation. Unfortunately, there are no reliable estimates of this number for the coming decades. There are only goals and aspirations. For lack of more reliable data, it was assumed that the EHV program would be a success if the number of battery powered over the road vehicles would increase from the few thousand currently registered to approximately 8 to 9 million in the year 2000, consistent with DOE's goals for an electric and hybrid vehicle fleet (4-1). The projected twenty year growth in the population of battery powered road vehicles is coincidental with the historic growth in the registration of all automobiles in the US between 1900 and 1920 (4-2). As shown in Figure 4-1, the population of registered automobiles in the U.S. increased from a few thousand in 1900 to 8 million in 1920. It was assumed, in the absence of other marketing data, that given the same start and end points in terms of registrations, the rate of growth of EHV's during the next twenty years is likely to track the historical increase in automobile registrations during the first twenty years of this century.

Based on these growth projections, the cost of subsidizing EHV's would increase with the size of the fleet, which would increase non-linearly with time. Subsidizing EHV's for the next ten years would be significantly less than expensive than subsidizing them for the next twenty years. In the first case, approximately 500,000 vehicles would be involved, while in the latter, subsidies would be applied to over 8 million vehicles.

4.3 INSURANCE POLICY ANALYSIS

The policy questions relating to insurance result from the barrier which product liability exposure creates for a distributor or retailer when the manufacturer is small, from the desire to protect the consumer when the manufacturer's assets are inadequate, and from the need of the consumer to protect himself through insurance when the product is "new" to the market. Electric vehicles must compete on equal terms with ICE vehicles if they are to attain a sustained growth in their use over the next decade. At present, electric

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(4-1) M. Savitz, "Progress in the EHV Program," Testimony before House Sub-Committee on Energy Research and Production, U.S. Congress, Washington, DC, November 29, 1979.

(4-2) Motor Vehicle Manufacturers Association of the United States, Inc., "Motor Vehicle Facts and Figures '80," p. 23, MVMA Statistical Department, Detroit, MI, 1980.

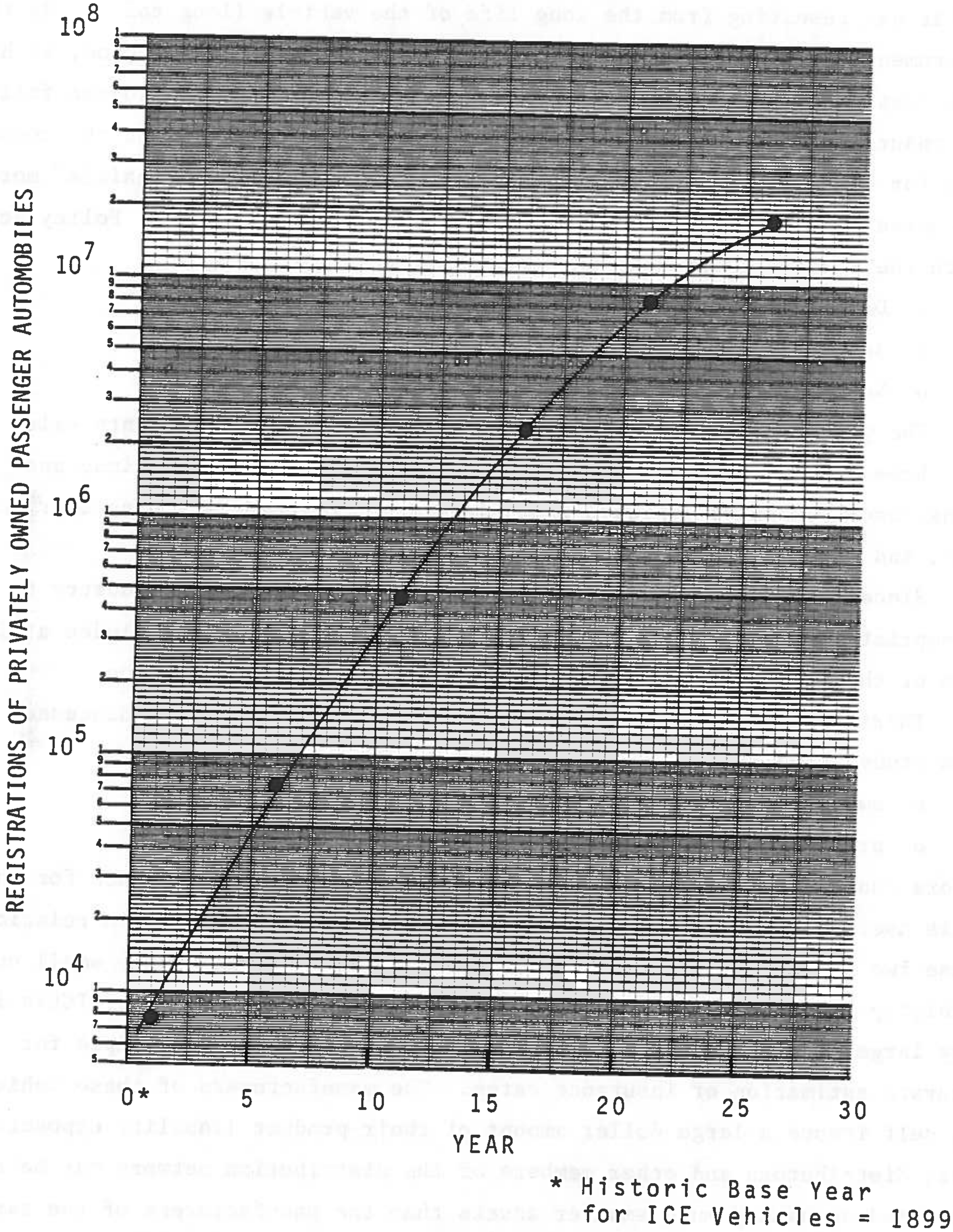

FIGURE 4-1. GROWTH IN PASSENGER CAR REGISTRATIONS DURING THE FORMATIVE YEARS OF THE U.S. AUTOMOTIVE INDUSTRY.

vehicles are manufactured by small businesses with limited assets. Product liability insurance for these manufacturers is expensive because of the unknowns associated with "new" products and because of the continued exposure the underwriter has resulting from the long life of the vehicle (long tail). If the government seeks to promote a particular product as a societal good, it has some responsibility to protect the consumer from accident or product failure. The insurance costs associated with manufacturers' liability and the consequent need for consumer protection will tend to make the "electric vehicle" more expensive and thus less likely to develop consumer acceptance. Policy actions which the federal government may employ include:

- o Direct Insurance or Reinsurance
- o Regulations or Standards
- o Subsidy through large purchases

The government may also choose to take no action. Precedents exist for all three policy options. At present the government is in the insurance and reinsurance "business" through flood insurance, Price-Anderson nuclear insurance, and veterans' life insurance.

Since there are both needs and difficulties for the EHV industry to secure appropriate product liability risk protection, this section includes a discussion of those alternatives to provide appropriate risk protection.

There are two issues concerning insurance which have been discussed in this study, namely:

- o owners and operators liability insurance
- o product liability insurance.

Before considering alternatives to the current status of insurance for the EHV, it is useful to restate the differences between ICEVs and EHVs in relation to these two issues. First, ICEVs are manufactured by a relatively small number of highly capitalized firms. Second, the operating population of ICEVs is very large, and as such presents a statistically significant sample for accurate estimation of insurance rates. The manufacturers of these vehicles may self insure a large dollar amount of their product liability exposure. Their distributors and other members of the distribution network may be characterized as having much smaller assets than the manufacturers of the cars.

For EHVs, however, these relationships do not hold. Referring to the review article on EHVs published in Motor Trend magazine (September 1979) one can note the small business complexion of the EHV industry. Except for the General Motors van and the cars made by Chrysler Corporation and General

Electric (under Department of Energy sponsorship) all other manufacturers are small. Some of these small manufacturers may use cars built by a major auto firm, converting these cars into EHVs. However, it is clear that the assets of the majority of the EHV manufacturers are small, leaving little security against damages caused by a major design or manufacturing defect. As a result, other participants in the distribution and sale of the EHV product may incur levels of potential liability which could prevent the formation of a distribution network sufficient for the desired acceptance of the product. Moreover, the consumer would, under these circumstances, be inadequately protected.

On the issue of owner/operator liability, the paucity of accident data, the small number of electric vehicles presently in use and their geographic dispersion combine to make assessment of risk difficult for the insurance industry. This uncertainty is compounded by the fact electric vehicle performance characteristics may imply an accident probability which differs appreciably from that of a comparable ICE vehicle because of limited acceleration and road performance. There is also the absence of information on repairability costs. As discussed in more detail in Chapter 2, obtaining a statistically representative data base from the operation of 5,000 to 10,000 EV's in a structured environment would provide much of the needed data, even though there might still be some questions as to the applicability of accident data obtained from the operation of commercial EV fleets to the accident risk associated with EV's used for personal transportation. However, this lack of information has not been critical to date because there are so few EV's being used in personal transportation. Until the necessary data are collected, the insurance companies have been willing to treat EV's no less favorably than other automobiles.

However, federal policy alternatives were considered in dealing with both of these issues. Starting with policy alternatives regarding product liability, four issue areas were defined:

I. Availability of EHV Product Liability Insurance

II. Affordability of EHV Product Liability Insurance

III. EHV Consumer Protection

IV. EHV Product Acceptance

There is an interaction between these issues. For example, increasing the availability and affordability of insurance helps to assure that any consumer injured as a result of a product "defect" would be compensated and also helps to remove barriers to the introduction of the EHV.

Since the issues of availability and affordability of liability insurance may be approached with similar alternatives, they will be discussed together. The issues and alternatives considered were also extensively examined in the Interagency Task Force study referenced in Chapter 2 (4-3) as they applied to the product liability insurance question for all products.

The policy alternatives affecting availability and affordability of insurance are:

A. Direct federal insurance
B. Federal reinsurance
C. Assigned risk plans
D. Mandatory risk pooling

4.3.1 Direct Federal Insurance

In considering the possible role of the federal government providing product liability insurance for EHV manufacturers, it is important to recall that one of the underlying legal concepts of product liability law, whether founded in negligence of in strict liability, is to shift the cost of physical damage from the injured to the one deemed responsible. For the federal government to either provide coverage where unavailable or at lower rates than available, it would seem that strong policy reasons would have to be identified. Among those few direct federal insurance programs which have been developed are the Flood Insurance Program and the Nuclear Energy Liability Insurance Program. These and other programs were noted in the Task Force study as having required federal action due to unusual circumstances. In the case of flood insurance, it was unavailable from the private insurance sector. Those who most wanted coverage had a high risk of exposure and those with almost no risk of exposure did not need or want insurance. The private insurers had no way to spread the risk. The nuclear energy liability issues related to the magnitude of the potential liability and the resources of industry to withstand such an exposure. In addition, the nuclear energy issue represented a substantial commitment not only of the federal government but also of major industrial organizations. The need for direct federal insurance to assist availability and affordability of product liability coverage for EHVs does not currently appear to approach the criteria expressed by precedent. Furthermore, the conclusion of the Task Force in commenting on the insurance approach taken in the Swine Flu Immunization Program and in noting that direct federal insurance would allow a manufacturer to externalize some of its risk-creating activity stated.

(4-3) Interagency Task Force on Product Liability: Final Report, U.S. Department of Commerce. PB 273220 (November 1977).

"It is our judement that this consequence could only be justified in the rate situation when there was a special public need for a product and it only could be made available if the Government did assume a portion of the manufacturer's tort liability."

Direct federal insurance of EHV's currently does not meet this test and is not an appropriate alternative.

4.3.2 Federal Reinsurance

Reinsurance refers to that process in which a primary insurer transfers a portion of the liability coverage to other insurers. However, reinsurance is not effective unless there is an insurer willing to accept the first level of risk at rates which the manufacturer views as affordable. The question of affordability of the first level of insurance is somewhat mooted if the federal reinsurance rates are so low that the primary insurer would pass them through to the manufacturer and the total coverage is then both available and affordable. The Task Force noted that as the government is forced to accept a greater proportion of the total liability through a reinsurance program, it gets closer to being a de facto primary insurer. The result is similar to that is a direct federal insurance program. In summary, since reinsurance alone soes not assure primary coverage and strong policy reasons do not exist to support a de facto direct insurance alternative, federal reinsurance is not an appropriate alternative.

4.3.3 Assigned Risk Plans

Assigned risk plans are designed to provide coverage for those who are unable to obtain insurance coverage in the voluntary market. They have been primarily used for automobile owner/operator liability insurance coverage to provide compensation for those injured by high risk owner/operators. Therefore, this alternative addresses the question of availability of insurance. These plans are structured on a state-by-state basis, usually by legislative directive. Since product liability claims might be filed in any state and since there is a dispersion of manufacturers and vendors, an assigned risk plan to provide coverage for product liability insurance would have to be a federal program to be effective.

However, in specifically considering this alternative for the product liability question, the Task Force noted that the inherent characteristics of assigned risk plans are such that they

"seriously compromise the potential value of this remedy in the area of product liability."

This alternative was not considered further.

4.3.4 Mandatory Risk Pooling

Risk pooling is the process by which rate determinations for high risk products are grouped with the experience of the low risk products. The result is an overall levelling of rates--increased for the low risk and decreased for the high risk. Such pooling is generally not voluntarily created. An example of a pooling provision would be a medical malpractice program mandated by legislation. Since such mandated risk pooling is a forced subsidization of the high risks, strong policy factors such as unavailability or enormously high rates (possible the equivalent of unavailability) in an area of vital concern is a necessary prerequisite to such a program. This alternative does not seem appropriate for EHV product liability insurance.

4.3.5 EHV Consumer Protection and Product Acceptance

Aside from insurance mechanisms, other aspects of the EHV product liability interests require a balancing of the public policies to assure consumer protection and to assist EHV product acceptance. This section addresses this balancing of interests.

There are two essential differences between EHVs and ICEVs namely, performance and the presence of the battery pack (absence of a gasoline tank except for hybrids). The reduced performance characteristic of an EHV may be likely to result in a different use pattern by the individual EHV owner, and quite possibly some differences in owner characteristics. These differences in drivers as well as vehicle performance may make EHVs less susceptible to accidents on one hand or the lack of acceleration may increase the risk on the other. What is important, however, when considering product liability is the possibility of a design or manufacturing defect which results in damage to persons or property. Since there are a large number of small manufacturers, many undercapitalized, in the EHV industry, the possibility of design or manufacturing defects may be larger than is reasonable for consumer use.* This risk may also be affected by the presence of the battery pack and the need for the vehicle owner to recharge the batteries frequently. The act of recharging by the individual consumer may well be an increased product safety risk. The product liability insurance issue is most applicable to the use of EHV's by private consumers, rather than by industrial or commercial firms in that such

*At present, there is not a sufficient statistical base to prove or disprove this thesis.

firms can take some of the risk by executing hold harmless agreements* for the benefit of the manufacturers. Incentives for this might well be their own business interests.

4.3.6 Owner/Operator Insurance

Turning to the question of insurance for owner/operators of EHVs, this is not presently a barrier to vehicle ownership and would not be where ownership was by commercial or industrial firms. Electric vehicle owners have been able to obtain insurance under essentially the same terms as for ICEVs. In effect this constitutes risk pooling by the industry. Any resulting bias towards EHVs would be eliminated if a significant statistical base on the over the road operation of EHVs were available. The demonstration program sponsored by the government is of sufficient size to yield statistically valid data for insurance rate setting if the demonstration locations are properly selected. In structuring the demonstrations it is important that a "normal" population of users be selected or that the selected user group be comparable to a group using ICEVs under similar or correlatable conditions. In summary, the owner/operator insurance issue does not seem to be an institutional barrier now. All that is needed is experience, much of which may be gained through a structured government sponsored demonstration program.

4.3.7 Insurance Policy Conclusions

By excluding or reducing the participation of the consumer from the early market of electric vehicles, some product liability problems can be reduced. The federal government, through its demonstration program, could encourage industrial or commercial fleet purchases which would stimulate the EHV industry, permitting the small manufacturers to operate with a sufficient profit margin and vehicle volume to bring about the early growth of the industry and some product acceptance. Alternatively, a commitment towards extensive federal purchase and use would stimulate the industry. As a result of this approach, sufficient statistical data on both product defects and operator liability could be gathered. However, the distribution network, upon which

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*Hold harmless agreement. A contractual arrangement whereby one party assumes the liability inherent in a situation, thereby relieving the other party of responsibility. Such agreements are typically found in leases, and easements. Agreement or contract in which one party agrees to hold the other without responsibility for damage or other liability arising out of the transaction involved. (Black's Law Dictionary, 5th Edition, p. 658, West Publishing Co., St. Paul, MN, 1973).

individual consumer purchases depend, might not be developed as quickly under this approach. The mature market will see the entry of major auto manufacturers into the EHV field, making the product liability insurance issue moot. It may be an appropriate time to encourage such entry through the use of program funds, CAFE standards inclusion of the EHV, tax credits, etc.

Table 4-1 summarizes the alternatives considered in each of the four product liability issue areas. Those alternatives which limit exposure of the product to consumers and provide an opportunity for manufacturing and operating experience are viewed as recommended alternatives at the present time.

4.4 Home Base Recharge

There are two aspects to the question of recharging EHVs at a home base, namely:

- o the ability of the utility to meet the demand for electrical capacity, and
- o the cost of recharge facilities to be carried by the EHV owner/operator

The availability of electricity supply for the implementation of an electric or hybrid vehicle commercialization effort is discussed in Appendix C in terms of the availability of home base recharging facilities. Each of these issues implies a different family of possible government actions.

4.4.1 Utility Issues

It was concluded in Chapter 3, that, nationally, utilities had sufficient baseload generating capacity to meet the additional demand for electricity that would be created by a fleet of 8 to 9 million EHVs in the year 2000, provided that recharging of these vehicles is carried out under strict load management. Only in a few instances, for specific utilities with fairly flat diurnal profiles, would there be insufficient off-peak capacity to support a significant EHV fleet.

The development of an electric vehicle fleet will have a significantly different impact on the costs and revenues of an electric utility depending on whether electric vehicles are recharged on an unrestricted time of day basis, or recharged only during off-peak hours. An estimate of the marginal impact of an electric vehicle on electric utility revenues as a function of recharge scheduling is presented in Table 4-2. For unrestricted recharging, it was assumed that the utility would have to increase its generating capacity by a factor equal to 1.25 times the average demand of an electric vehicle. The lower value corresponds to the average demand for an electric vehicle charged from a 120 volt household outlet, with an assumed peak current

TABLE 4-1 SUMMARY OF POLICY ALTERNATIVES TO ADDRESS THE PRODUCT LIABILITY QUESTION

ISSUE	POLICY ALTERNATIVES	METHODOLOGY	IMPLEMENTATION	RECOMMENDATION
I. Insurance Availability	A. Direct federal insurance	Underwrite liability Risk	Federal insurance program legislation	No
	B. Assigned risk plan	Insurers required to accept all insureds	Legislation	No
	C. Federal reinsurance	Federal government accepts excess liability	Federal insurance program legislation	No
II. Insurance Affordability	A. Direct federal insurance	Underwrite liability risk at rates far lower than market conditions indicate	Federal insurance program and subsidy legislation	No
	B. Mandatory risk pooling	Use of insurer's stronger product lines to support weaker product lines	Legislation	No
	C. Federal reinsurance	Federal government accepts excess liability at lower rates than market	Federal insurance program and subsidy legislation	No
III. Consumer Protection	A. Federal support of insurance	Any federal alternative to enhance insurance availability or affordability.	Legislation	No
	B. Limitation on product availability	Restrict sales or federally supported program to selected commercial users.	Program administration.	Yes
IV. EHV Product	A. Federal support of insurance	Any federal alternative to enhance insurance availability or affordability	Legislation	No
	B. Limitation on product availability	Restrict sales of federally supported program to to selected commercial users	Program administration	Yes
	C. Federal purchase of EHVs	Use of EHV in federal functions	Program administration	Yes
	D. Participation of major automobile producers	Stimulate participation by funds, tax credits, CAFE standards, etc.	Program administration and legislation	Yes

TABLE 4-2 MARGINAL IMPACT OF AN ELECTRIC VEHICLE ON ELECTRIC UTILITY REVENUES AS A FUNCTION OF RECHARGING SCHEDULING

	Unrestricted Recharging	Restricted Off Peak Recharging
Increase in Power Demand/Vehicle, kW	1.2-2.3 (average value)	9.2 (peak value)
Increase Power Supply Required/Vehicle, kW	1.5-4.1[a]	- [b]
Additional Capital Investment Required of Utility per Vehicle, $	1600-2000[c]	50-190[d]
Marginal Cost/Revenues per Vehicle, $/year		
Annual Cost of Additional Capital Investment @ 15%/year	160-430	8-28
Additional Operating Costs (5000 kWh/yr use)	99[e]	60[f]
Total of above	250-529	68-88
BEP of Electricity, ¢/kWh (5000 kWh/yr use)	5.2-10.6	1.4-1.8

a) Based on 125% of additional demand

b) Based on available off-peak capacity - valid for electrification of up to 15% of the Light Transportation Vehicle fleet (passenger cars and light trucks with a gross vehicle weight of less than 10,000 lbs).

c) Based on 1977 New Facility Cost of $700/kW of additional system capacity

d) Based on cost of separate overhead service and time controlled meter on existing service with dual rate meter

e) Based on 1977 average operating and maintenance costs per kWh of large private utilities

f) Based on 1977 average fuel costs per kWh of large private utilities of 24 amperes and a 17 hour charging period. The higher value corresponds to the average demand for an electric vehicle charged from a 230 volt outlet, with an assumed peak current of 40 amperes and a 6 hour charging period. These allocations for additional demand do not include any factors of safety for a greater than average recharging rate during on-peak hours.

For restricted off-peak recharging, it was assumed that no additional capacity would be required by the electric utilities to support the EV fleet that is projected to develop over the next twenty years.

The additional capital cost needed to provide service for EV recharging without tine-of-day restrictions was based on the marginal cost of additional facilities installed by private utilities in 1977, as shown in Table 4-3. The additional capital costs for restricted time-of-day recharging represent the additional distribution costs for metering off-peak power, as given in Table C-1 of Appendix C. It was assumed that the utility would opt either for dual metering of an existing service connection or possibly provide a separate overhead service to selected residential customers. Utilities which provide underground service would not provide a separate service because of the high additional costs. It should be noted that these distribution costs, which are based on 1978 data, are somewhat inflated (by about 8%) when compared to the marginal capital costs assigned to unrestricted recharging, and the operating cost data. This results in a bias of $1 to $3 in the estimate, which is well within its uncertainty limits.

The BreakEven Point (BEP) of electricity is defined as the rate the utility would have to charge an electric vehicle owner for the 5000 kwh used annually for EV recharge in order to cover the costs of providing this electricity. It is to be noted that the BEP for electricity based on unrestricted recharging is much higher than the BEP based on restricted off-peak charging. The former is also higher than the average 1977 price of 4¢/kwh for electricity in the U.S. If this average price were applied to EV recharging, with unrestricted recharging, other users of electricity would be supporting EV owners, whereas with restricted off-peak recharging, the converse holds. If it is assumed that the utilities would sell the electricity at 20% above costs, they could charge EV owners that recharge on an unrestricted basis 6¢/kwh to 13¢/kwh for electricity, but only approximately 2¢/kwh for EV owners that would recharge on a restricted off-peak basis, based on 1977 fuel prices. These costs will increase as the cost of fuel to the utilities increases.

As more current cost and operating data become available, it is expected

TABLE 4-3

MARGINAL CAPITAL COSTS OF 1977 FACILITY INCREASES
FOR CLASS A+B INVESTOR OWNED ELECTRIC UTILITIES

	Installed Capacity 12/31/77	Installed Capacity 12/31/76	1977 Increase In Capacity	Cost Of Additions 1977	Retirements 1977	Net Cost Of Additions 1977	Unit Cost Of 1977 Net Addition
	GW	GW	GW	$\$10^6$	$\$10^6$	$\$10^6$	$/kW
Fossil Steam Plants	336.91	321.07	15.84	5058.7	225.1	4833.6	305
Nuclear Plants	37.65	34.53	3.12	3520.9	90.4	3430.5	1100
Hydraulic Plants	21.51	22.52	(0.99)	37.5	3.4	34.1	-
Other Generation Plants	37.16	36.15	1.01	281.2	11.9	269.3	266
Total Production Plants	433.23	414.26	18.97	8898.4	330.9	8567.3	452
Total Electric Utility Plant				14648.8	1162.2	13486.6	711

*Includes Production Plants, Distribution Network, and Other Capital Facilities.

(4-4) DOE/EIA - 0044 (76) Statistics of Privately Owned Utilities in the United States 1976 (April 1978)

(4-5) DOE/EIA - 0044 (77) Statistics of Privately Owned Utilities in the United States 1977 (January 1979)

that the spread in these calculated costs will increase. While both costs will rise, the rapidly increasing marginal cost of new facilities will make the true costs of unrestricted recharging of electric vehicles even more expensive, as indicated in Figure 4-2. The data in Figure 4-2 indicate that the cost of fossil fuel steam power plants is now significantly higher than the $305/kW given in Table 4-3, and will continue to rise. The total cost of new electric power systems has increased and will increase in a like manner, as underscored by the following two news items. The January 31, 1980 issue of The Energy Daily reported, first, that the estimated completion cost of the Midland nuclear cogeneration plant (1,300 megawatt) in Jackson, Michigan had risen to $3.1 billion, or about $2400 per installed kilowatt. The second item reported in the same issue was that the Public Service Company of Colorado was postponing the construction of a 1,000 megawatt coal fired plant that had an estimated cost of $1 billion. From these recent estimates, one concludes that the marginal cost of electrical generating capacity currently ranges between $1,000 and $2,400 per kW used in Table 4-2. This further reinforces the argument that strict load management of EV recharging will be in the utilities' own self-interest.

The utilities contacted indicated they were interested in EHVs principally as a load management tool (4-7, 4-8) that would allow them to improve the utilization of their baseline equipment. The major issue that presents itself is establishing incentive rates that would encourage off-peak recharging of EVs. While utility rate regulation is generally more of a state than a federal responsibility, except where interstate sales are involved, with the explosive escalation in the cost of generating plants, in order to prevent undue escalation in the price of electricity to consumers, the issue of load management has become of national concern. Currently, under the Public Utility Regulatory Policies Act of 1978 (PURPA), every utility has the mandate to consider all possible approaches to load management. These methods can entail either active techniques (which allow a utility to control or displace specific loads for specific time intervals) or passive techniques (which encourage the consumer to voluntarily shift loads to off-peak periods). Since PURPA already provised the regulatory encouragement for the establishment of off-peak rates, given the utilities self-interests to encourage off-peak recharging of electric vehicles, further Federal action does not seem to be required with regards to this issue.

(4-7) David Hesketh, Engineering Department, Boston Edison Company, Boston, MA, Personal Communication, September 26, 1979.

(4-8) K. A. O'Connor, Energy Services Dept., Long Island Lighting Co., Mineola, NY, Personal Communication, September 19, 1979.

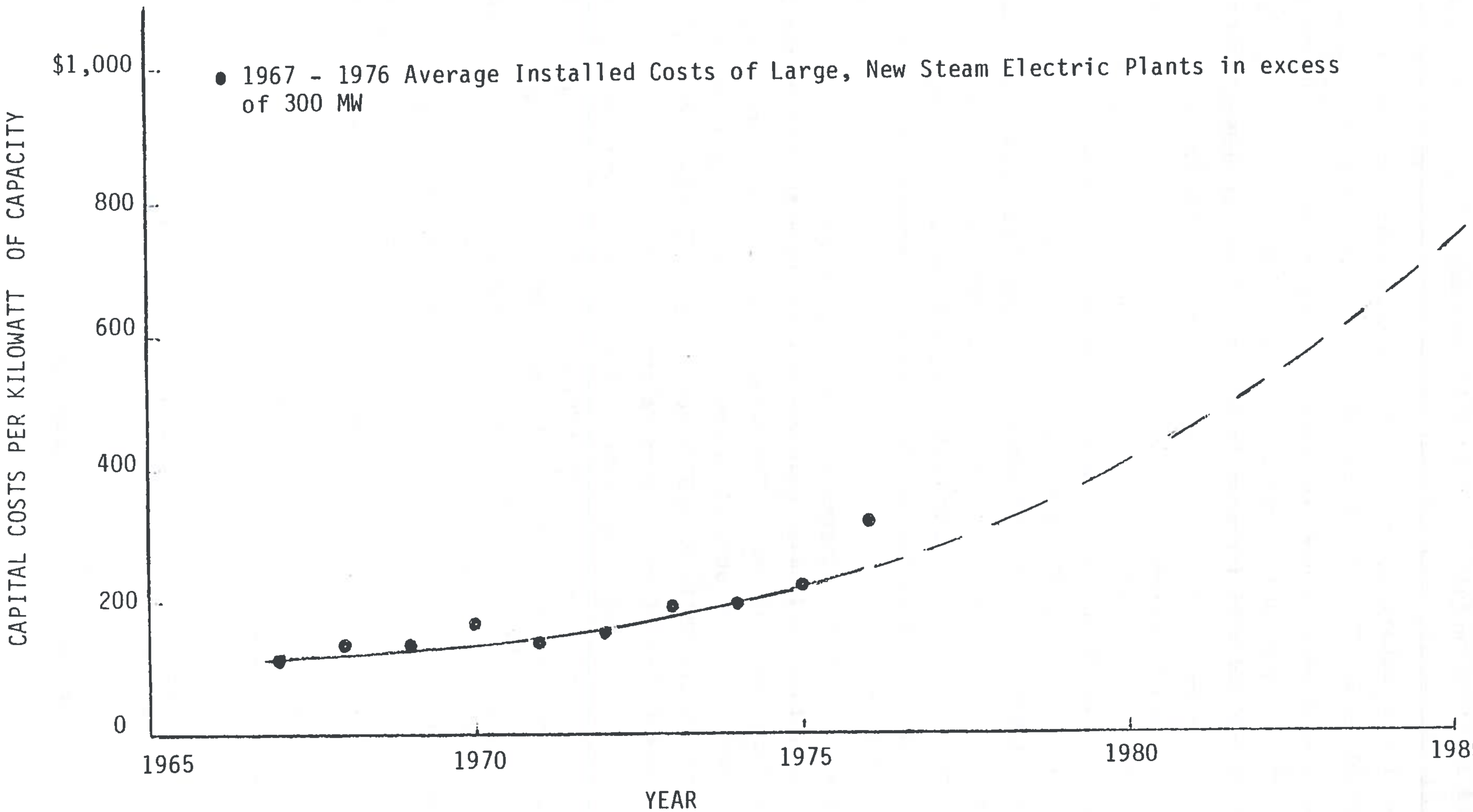

FIGURE 4-2. ESCALATION WITH TIME OF THE CAPITAL COSTS OF STEAM ELECTRIC POWER PLANTS

(4-6) Projected Costs of Large Coal Fired Electric Plants by R. N. Bergstrom & N. F. True, Electric Light & Power, February 1979, p. 57.

4.4.2 Incentive for Home Base Recharging Facilities

During the early stages of commercial development of EVs and EHVs, ownership will tend to be limited to those users who can provide battery recharging capability, principally at their place of residence and business. The number of owner occupied housing units with off-street parking and the type of electric service to permit electric vehicle recharging has been estimated at about 20 million. However, in almost all cases it would be necessary to provide a separate branch line, possibly separately metered, to permit EV recharge. Indoor or garage recharge will require forced ventilation so that explosive mixtures of hydrogen and air do not accumulate.

Potential EV fleet operators will, most probably, have both the garage space and the electrical capacity available. The principal requirement for this class of EV owner will be providing for the recharge outlet wiring and the forced ventilation. The cost of providing these facilities both for the fleet operator and individual owner constitutes a cost disadvantage for the commercialization of electric vehicles that one might perceive to be an institutional barrier since such facilities are not needed for ICEVs. Based on the results of Harshberger's study (4-9) the costs (in 1979 dollars) for electrical system modification are estimated to range from $90 to $430 for individual installations (exclusive of any cost to the utility); and from $350 to $780 per vehicle for fleet operators who would require a multivehicle recharging capability.

The Federal government could partially (or completely) subsizide the installation of such facilities as a visible incentive to promote the expanded use of EHVs without having to subsidize the vehicles directly. The cumulative costs to the government of such subsidies over a twenty year period in which the EHV population would grow to 8.2 million vehicles are given in Figure 4-3 for various assumed subsidy levels ranging from 10 percent to 100 percent of the installation costs of EHV recharging facilities. These results are based on the following assumptions:

o Installation cost for recharging facilities are $300 per vehicle for single vehicle recharging facilities, and $500 per vehicle for multi-vehicle recharging facilities that would be used by fleet operators.

o 80 percent of EHVs would be recharged at single vehicle recharging facilities (i.e. owned by individuals), and 20 percent would be recharged at multi-vehicle facilities.

o The rate of growth of the EHV population, discounting vehicle

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(4-9) W. G. Harshberger, "Installation Costs for Home Recharge of Electric Vehicles." General Research Corporation, Report RM 2291, Santa Barbara, CA, January 1980.

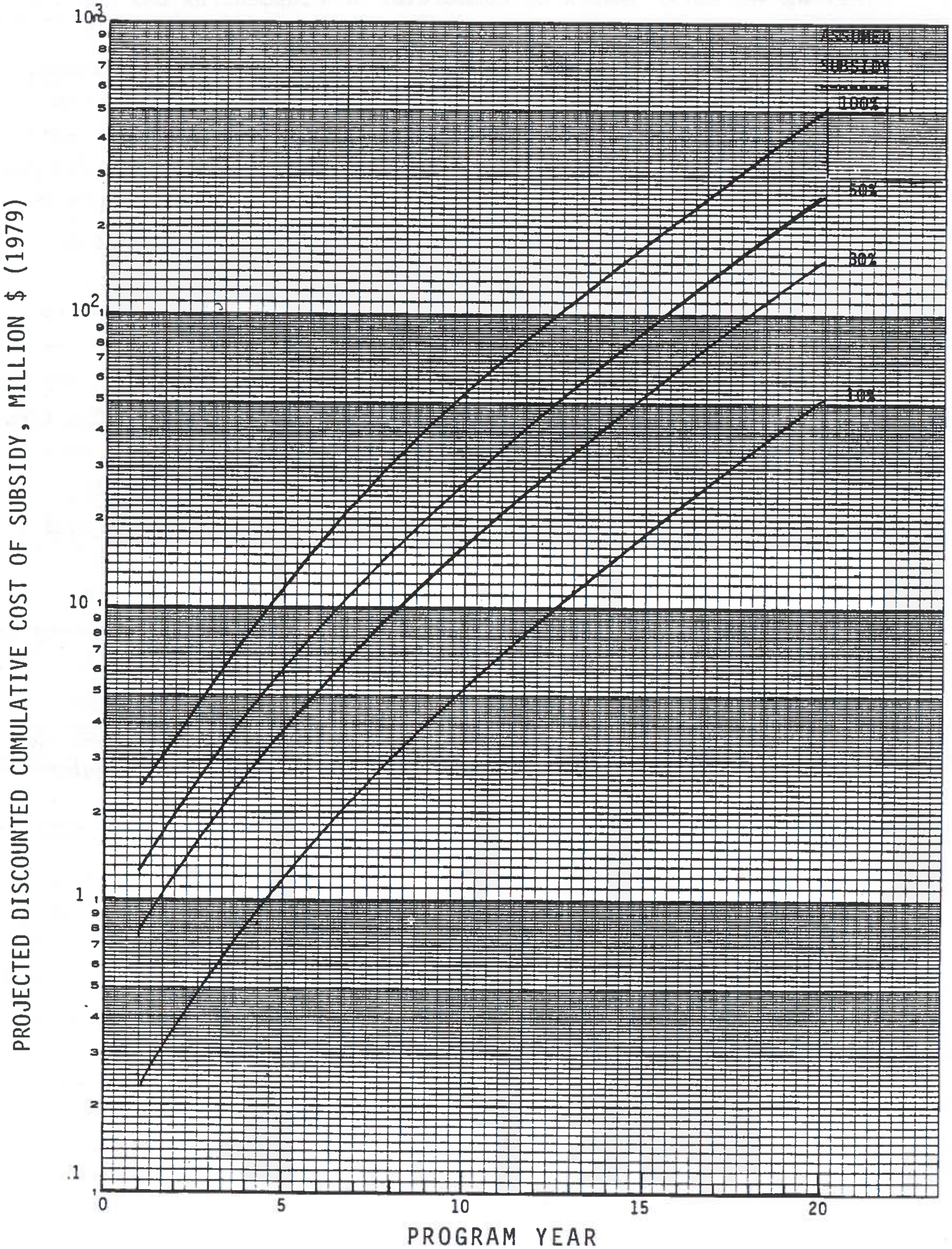

FIGURE 4-3 PROJECTED COST OF SUPPORT OF HOME BASE RECHARGING FACILITIES FOR DIFFERENT ASSUMED SUBSIDY LEVELS VS. TIME

retirements, would follow the curve given in Figure 4-1.

o A discount rate of 10 percent per annum is applied to future expenditures.

o The sale of EHVs and the installation of recharging facilities does not add to the GNP, and does not result in any additional cash flow to the Treasury.

Aside from the subsidy level, the principal factor influencing costs would be the life of such a program. A 5 year program would cost less than $6 million, even with a 50% subsidy level, but would affect the installation of recharge facilities for only 48,000 vehicles. A twenty year program would cost between $50 million and $250 million over a subsidy range of from 10 percent to 50 percent.

A criterion for the desired life of such a program could be a level of introduction of EHVs equal to the production capacity of two automotive assembly lines. Based on a nominal assembly line capacity of 200,000 vehicles per year, one could argue that EHVs would have been commercially launched, and further financial incentives would no longer be required, when the rate of introduction of EHVs reached a level of 400,000 units per year. Using Figure 4-1 as a guide, such a level of introduction would be reached in the fifteenth year after the cumulative sale of 1.7 million EHVs. The discounted cost of subsidizing the recharging equipment for these vehicles would range from $18 million at a 10 percent subsidy level to $180 million at a 100 percent subsidy level.

A number of different existing mechanisms could be used to distribute these subsidies, and could vary depending on the parties at issue and the level of subsidy desired.

For individual purchasers of EHVs, a tax credit based on a percentage of the cost of recharging facilities would be a simple method of distributing such a subsidy. This has been the method of promoting the use of solar heating in homes. A 40 percent tax credit is now available to individuals for the installation of solar heating facilities up to a cost of $10,000. A drawback to this approach is that it would not readily benefit an EV purchaser who was a renter. Statistically, such a bias against renters should have little effect on the early market for EHVs since nearly 80 percent of all automobile ownership is associated with home owners. Furthermore, ownership of more than one vehicle per household is much more prevalent for home owners than for renters. Thus, the early market for EHVs should not be constrained by the recharge limitations imposed upon residential renters.

The political implications of such a subsidy are that it would favor areas where private home ownership is dominant, i.e. non-urban areas. In order to promote market penetrations of EHVs in urban areas, it would be necessary to consider subsidies to landlords for the installation of recharging facilities for use of their tenants, or to municipal authorities for the installation of overnight recharging facilities in municipal garages available to the public for a fee. In terms of providing an incentive to private landlords, this could take the form of an enhanced investment tax credit. However, it is questionable whether such an incentive, unless it were very high, would stimulate landlords to make recharging facilities available during the initial phases of EHV market development. Furthermore, availability of such facilities would not guarantee that they would be used--the landlord has to have tenants who would have purchased EHVs. Subsidies attractive enough to promote installation of recharging facilities by landlords could result in the installation of many more such facilities than would be required in terms of tenants owning EHVs.

A more controllable method of providing overnight recharging capability to urban renters would be federal transfers to cities from the Department of Housing and Urban Development (HUD) for the installation of a limited number of overnight recharging facilities in municipal garages for resident owners of EHVs, as discussed in more detail in Appendix C. The benefits, besides providing a measure of political equity in the distribution of funds associated with such a subsidy plan, would include some alleviation of problems associated with on-street overnight parking in urban areas. Support could take the form of a Community Development Block Grant, under Title 1, Housing and Community Development Act of 1974 (PL 93-383), as amended by Title 1, Housing and Community Development Act of 1977 (PL 95-128), or a rehabilitation loan in association with such a grant. There have been numerous other precedents for federal assistance to municipalities for the construction of public works.

For commercial fleet operators of battery powered road vehicles, a tax credit supplementary to the normal investment tax credit (presently up to 10 percent based on the depreciation period), with a short, allowable depreciation period for an EHV, would be a suitable mechanism. Again, as a precedent, it should be noted that businesses that install solar equipment currently receive a 15 percent investment tax credit, over and above the standard investment tax credit they would normally receive.

Alternately, the subsidy could be distributed through guaranteed low interest loans, through established channels such as the banking system, the Rural Electric Administration, or through the utilities (including federal utilities) directly. The principle of the Solar Bank which, when authorized, would be able to give loans of up to $10,000 at interest rates of 6 points below the prevailing market rates could be extended to include electric vehicles. However, a loan incentive of 6 percent below market price would only provide an individual EHV owner with at most $18/year (based on a $300 cost), and a fleet owner with $30/year (based on $500 cost per vehicle); this may not be an attractive enough incentive.

The extent to which such a subsidy program would influence the purchase of an EHV would depend significantly on the relative costs and performance of a battery powered vehicle and a comparable ICE vehicle. Such a subsidy would be an effective inducement towards the purchase of a battery powered vehicle only if the consumer were to perceive such a vehicle to be of "comparable" value to an ICE vehicle for a given driving mode. At the moment, the first costs of both electric and hybrid vehicles are significantly higher than that of a comparable ICE vehicle, as discussed by Hamilton (4-10). Even with the mass production of battery powered vehicles, this cost differential would persist, and would be significantly greater than the costs of installing recharging facilities. In terms of performance, battery powered vehicles do not presently have the acceleration and range capabilities of ICE vehicles. While these may improve with technological advances, a battery powered vehicle will become attractive as a local mode of private transportation and thus comparable to an ICEV, only if the availability of petroleum fuel for ICE vehicles were severely restricted or uncertain, or if the price of this fuel were to increase disproportionately in relation to the price of electricity, so that operating costs of battery and ICE vehicles would become comparable, even after taking first cost differences into account.

4.5 RANGE EXTENSION

Range extension of battery powered road vehicles is necessary to permit the use of these vehicles as general personal transportation without relying solely upon homebase recharge of batteries. Without range extension support, electric vehicles will never be comparable to ICE vehicles in terms of their use as a means of transportation, and will be relegated to local fleet use and second car family use. The methods of range extension that were analyzed in this study, as discussed in Section 3 include:

- o battery swapping
- o transient recharging operations
- o an ICE-electric hybrid vehicle which uses a low horsepower ICE for sustained highway cruising.

From these analyses, it was concluded that, institutionally, the simplest means of providing range extension to a battery powered vehicle is to develop a range extension hybrid which could take advantage of the existing network of gasoline stations. As configured, this vehicle would operate in an "all electric" mode in urban driving, and use the ICE only under constant speed highway driving conditions. It has been estimated that such a vehicle would derive ~75 percent of its energy requirements from electricity, and only ~25 percent from petroleum (4-10). The major disadvantage of such a hybrid is that it detracts from the primary advantage of an electric vehicle--namely decoupling of private automotive transportation from petroleum fuel. Such a vehicle will also be technically more complex than either a pure electric or pure ICE vehicle. Finally, the petroleum conservation potential of such a vehicle may not be significantly greater than that which could be achieved with advanced, fuel efficient ICE vehicles.

The battery swapping range extension concept requires substantial capital investment in both battery inventory, and in a new type of "service station." In addition, this approach would require a substantial existing EV population in order to be viable. Transient recharge would not only be a slow and inconvenient method of range extension, but would also exacerbate the problems of utility capacity since this concept would require recharge during peak hours of electricity demand.

4.5.1 Battery Exchange

Battery exchange or swap overcomes the technological refueling time barrier for electric vehicles. Creating a battery exchange network may be difficult to achieve. Most of the problems that would present themselves in the the establishment of such a network appear to be amenable to a technological solution, but these barriers may be significant enough to prevent such networks from being established. Factors of concern include a significant capital investment, the need for battery leasing and standardization, potential environmental problems resulting from acid spills and accidents during exchange, and from explosions resulting from battery "gassing" during recharge.

(4-10) W. F. Hamilton, "The Potential of Range Extension Hybrid Cars," General Research Corporation, Report RM 2263, Santa Barbara, CA, October 1979.

4.5.1.1 Required Capital Investment

A very significant capital investment would be required to establish the network of stations needed to make the battery swap concept a successful range extension method for electric vehicles. The analysis of the capacity and investment costs for swap stations of different size (number of bays) and location were carried out by General Research Research Corporation (4-11), and is summarized in Section 3. As an example, a three bay urban swap station with provisions for battery recharge during off-peak hours (11 pm to 7 am) only*, would cost approximately $1.1 million dollars (1979), exclusive of the cost of the battery inventory. This station would exchange 192 batteries on an average day, and could exchange as many as 224 batteries per day, which would establish the required battery inventory. The investment in the inventory would depend on the type of battery involved. For purposes of this discussion, GRC's wholesale battery price of $1385 (4-11) will be assumed. The station operator has an additional investment of approximately $290,000 in battery inventory, so that the total investment in the station would be $1.4 million.

This investment is only the smaller part of the total investment required to operate a battery swapping network since the concept is only feasible in conjunction with battery leasing to user vehicles. There will be a significant investment associated with user-vehicle batteries. The size of the electric vehicle fleet a swap station can support will depend on the frequency with which batteries are exchanged. The premise of the GRC study was that home base recharging would be the principal means for refueling, and that battery swap would be carried out only infrequently to provide periodic range extension requirements. The station described above could support the operation of 5000 EVs if batteries are swapped on an average of once a month, but only 2500 EVs if the swapping frequency were increased to twice monthly. Assuming an average swap per month, an additional investment of $6.9 million would be required for the 5,000 batteries used by operating vehicles. This would raise the total capital cost of such a swap station to $8.3 million. This represents an investment of about $1,700 per associated EV ($300 of which is the investment

*Limiting battery recharging to one shift increases the number of chargers required, and thus the cost of the station. This provision is required to prevent the need for the recharge station to draw electricity during peak demand hours.

(4-11) C. A. Graver and L. Morecraft, "Electric Vehicle Range Extension: Battery Swapping Facilities," General Research Corporation, Santa Barbara, CA, RM 2290, March 1980.

in the swapping station itself and its in-house battery inventory), above and beyond the base vehicle cost.

The battery swap concept would require more than a single station to operate. GRC established that a density of battery exchange stations similar to the density of suburban shopping centers should be adequate. For an urban area such as Washington, DC, one could assume that ten 3-bay stations would constitute a reasonable network. This network would require the support of 50,000 EVs, and an investment of $83 million, $71 million of which would be in batteries, either leased to owners or in swap station inventory.

The established of a battery swap network will require a substantial capital investment, and is only feasible if there is a sufficiently large fleet of EVs in operation to sustain the network. This approach to range extension will not serve to stimulate the early market for electric vehicles for lack of a critical mass. Based on the growth curve given in Figure 4-1, even if all the EVs sold in the country were concentrated in one geographic area, it would take six years for the population to exceed the nominal critical mass of 50,000 vehicles.* The issue is that support of swap stations would only be of value after the initial market incubation period.

Support of a swap station could be expensive depending on the level of support. For purposes of calculation, it was assumed that two swap station networks, each capable of supporting 50,000 EVs, would be introduced in the seventh year of an EV support program. In the next 13 years, the number of such swap station networks would grow to 164 as the fleet of EVs grew to a population of 8.2 million. It was assumed that each network would cost $83 million in 1979 dollars. The total current discounted cost of installing these 164 networks would be $2.72 billion, assuming a 10 percent per annum discount rate.

4.5.1.2 Federal Incentives

One possible incentive to EV commercialization would be a federal subsidy of the cost differential of an ICE vehicle and an equivalent EV. This cost differential is essentially the cost of the battery. Thus, a financial incentive policy might partially subsidize cost of batteries for road battery powered vehicles. This subsidy could apply to all purchasers of EV batteries, whether for use in their own EVs, or for lease to other vehicle operators.

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*The number could be smaller if one considered smaller swap stations and smaller communities.

For purposes of calculating the possible cost of such subsidies, it was assumed that

a) the subsidy is proportional to the wholesale price of the vehicle battery.

b) the wholesale price of a vehicle battery is $1365 (1979 dollars)

c) the life of an EV is 12 years

d) the life of an EV battery pack is 3 years - a EV would require 3 additional new batteries over its lifetime

e) the subsidy would apply to replacement batteries as well as new batteries

f) no compensating cash flows to the treasury would occur.

The cost projections are presented in Figure 4-4 for assumed subsidy levels of 10, 30, 50 and 100 percent of the discounted cost of the batteries that would be in circulation over the first twenty years of the development of an EV fleet. The total discounted wholesale price of all batteries that would be used in the development of an 8.2 million EV fleet would be over $3 billion. The cost of a 20 year subsidy program would range from $330 million for 10 percent subsidy level to $3.3 billion for a 100 percent subsidy level. A 15 year program would cost approximately one-third as much.

For such a subsidy to be effective in competitive economic terms it would have to be able to lower the cost of an EHV to a vehicle user to a level such that the sum of the costs of battery ownership and electricity per distance travelled in an EV were equal to or less than the cost of fuel per distance travelled for a comparable ICEV.

Table 4-4 summarizes the estimated cost to an EV operator of either leasing or owning a battery that has a wholesale price of $1365 and a nominal 3 year life. Given the accounting assumptions used in developing this Table, the costs of either owning or leasing a battery are comparable. The cost of the battery is about $1150/year, or, assuming 10,000 mi/yr (16,000 km/yr) vehicle use, 11.5 ¢/mi (7.2 ¢/km) travelled. Given similarity in costs, an EV owner would be likely to opt for a battery leasing arrangement since it would offer a range extension possibility that is not available to a non-lessee, and eliminate the need to purchase the battery, thus lowering the acquisition price of an EV to a level comparable to that of an ICEV.

The cost of electricity per distance travelled will depend on the energy required to propel the EV and the cost of the purchased electricity. For purposes of this discussion, it was assumed that the specific energy

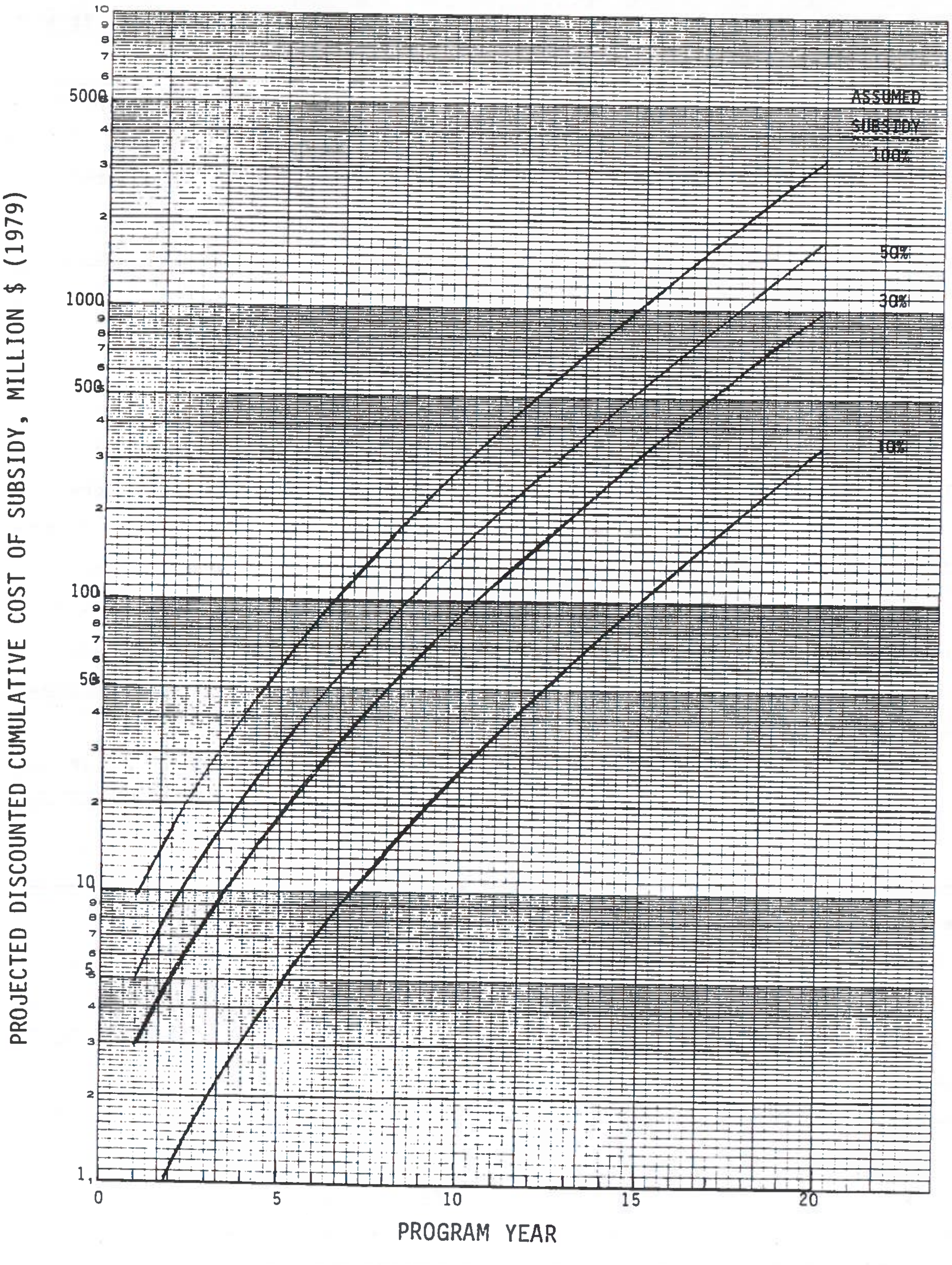

FIGURE 4-4 PROJECTED COST OF SUPPORT OF ELECTRIC VEHICLE BATTERIES FOR DIFFERENT ASSUMED SUBSIDY LEVELS VERSUS TIME

TABLE 4-4

COST OF BATTERIES TO EV OPERATOR

Battery Owner	Battery Lessor	Vehicle Owner
Battery Acquisition Price, $	1365	2730
Annualized Costs, $/yr		
Interest foregone @ 10% p.a.	137	273
Depreciation (3 year)	455	910
General and Administrative Expenses	233[a]	-[b]
Battery salvage credit[c]	(35)	(35)
Total	790	1148
Operational Profit, $/yr	273[d]	-[b]
Total, $/yr	1063	1148
Cost of battery swapping, $/yr	84[e]	-[b]
Annual cost of battery to vehicle operator		
Leased battery, $/yr	1147	
Purchased battery, $/yr		1148
Unit cost of battery to vehicle operator[f], ¢/mi(¢/km)		
Leased battery	11.47(7.12)	
Purchased battery		11.48(7.13)

Notes

[a]G&A expenses based at 17% of acquisition cost

[b]not applicable to individual battery purchaser

[c]Battery salvage assumed to be 2.5% of battery wholesale price

[d]Lessor profit assumed to be 20% of acquisition costs.

[e]Assumes 12 swaps at $7/swap

[f]Assumes 10,000 mi/yr (16,000 km/yr) vehicle use

requirement of an EV would be 0.5 kWh/mi (0.32 kWh/km) (at the wall plug) which is approximately the value used by GRC in its supporting study (4-9), and is also one of the objectives of DOE's near term electric vehicle program. The cost of electricity would range from 1¢/mi (0.6¢/km) to 6 ¢/mi (3.6¢/km) over a range of from 2¢/kWh for the assumed cost of electricity. The lower end of this range would be representative of the lowest cost of electricity that would be available in the U.S.—namely the Pacific Northwest region supplied with hydropower--while the upper end represents the cost characteristic of Northeastern utilities with mainly oil fired generators. The total cost of energy for an EV, i.e., the sum of costs of electricity and of the battery, could range from 12.5¢/mi (7.8¢/km) to 17.5¢/mi (10.9¢/km).

The energy cost of the ICEV that would compete with an EV, will depend on the fuel economy and on the cost of fuel (assumed for these calculations to be gasoline). These costs are summarized in Figure 4-5. This figure presents fuel costs per mile as a function of the price of fuel for vehicles that have an assumed fuel economy ranging from 10 mpg (9.2 km/l) to 80 mpg (33.8 km/l). The lowest value of fuel economy (10 mpg) corresponds to that achieved with the now obsolescent passenger carrying "gas-guzzlers," or to a light duty or urban delivery vehicle. The second value (20 mpg) corresponds to the mandated 1980 corporate average fuel economy. The value of 40 mpg is representative of the fuel economy in the urban driving cycle of the most energy efficient sub-compact automobile currently on the market. The highest value of fuel economy is representative of the fuel economy of limited performance ICE "minicars" currently being sold in France (4-12). Whether a market for such vehicles will develop in the U.S. is unknown at the present. However, should these vehicles become popular in the U.S. they would compare directly with EHVs in the second vehicle market.

The price of liquid fuel at which the cost of energy for an ICEV is equal to the cost of energy (as here defined) for an EV is presented as a function of ICEV fuel economy and cost of electricity in Figure 4-6. At current prices of petroleum fuel (~ $1.25/gallon), cost of energy for an EV is equal to the energy cost of ICEV with fuel economy of 8 to 10 mpg depending on the assumed cost of electricity. If the price of liquid fuel were to rise to $5/gallon, energy costs for EVs would be comparable to the energy cost of an ICEV with a fuel economy of 40 mpg at an electricity cost of 2¢/kWh, and of 28.5 mpg at an electricity cost of 12¢/kWh. If the EV were compared to an ICEV with a fuel economy of 80 mpg, the breakeven price of liquid fuel would range from

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(4-12) J. P. Norbye, "Continued Boom Seen For Mini Cars," Automotive News, December 22, 1980, p. 12.

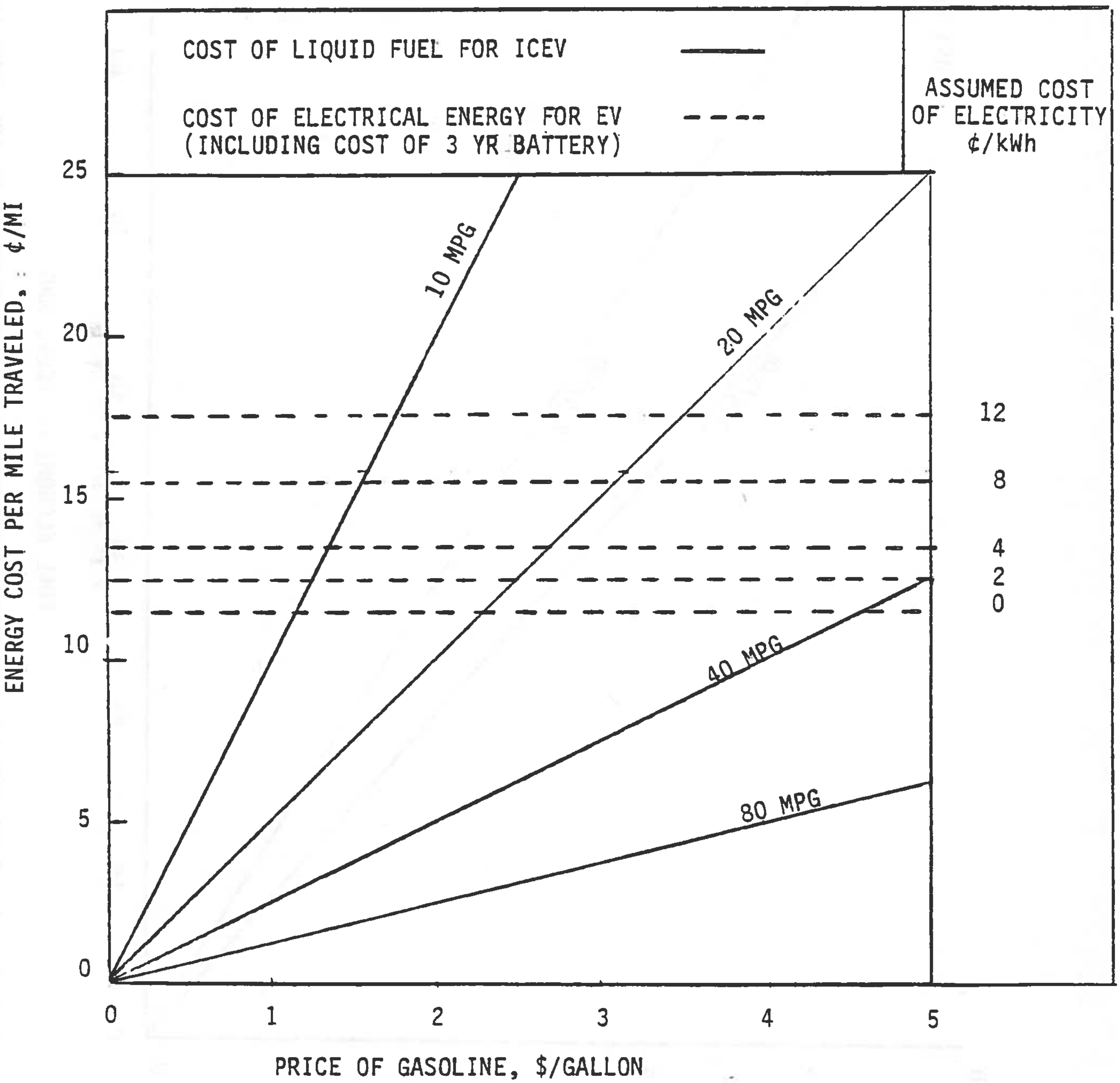

FIGURE 4-5 COST OF ENERGY PER UNIT DISTANCE TRAVELED FOR VEHICLES OF INTEREST TO THE STUDY

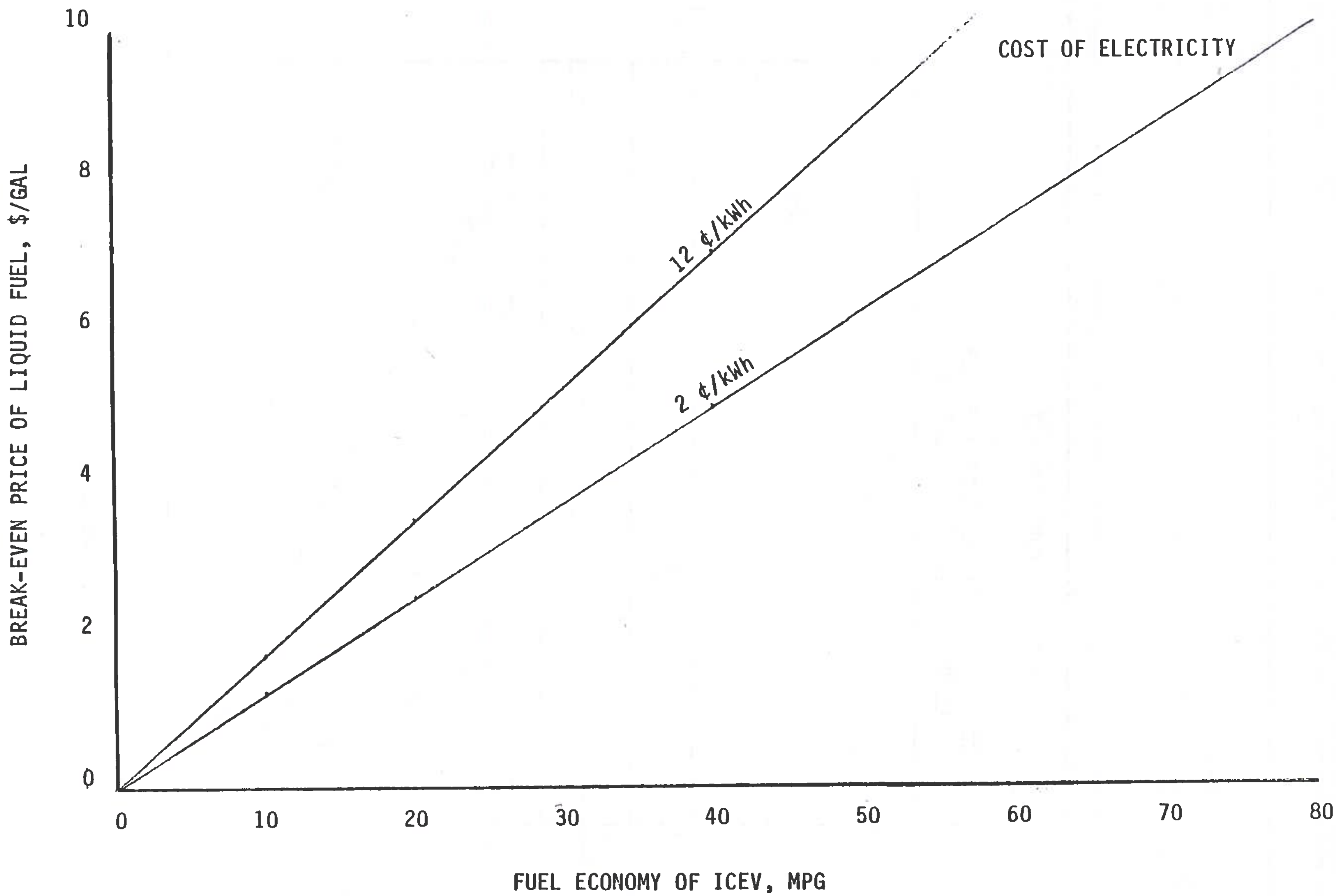

FIGURE 4-6 PETROLEUM FUEL COST AT WHICH TOTAL ENERGY COSTS OF EV AND ICEV ARE EQUAL AS A FUNCTION OF ICEV FUEL ECONOMY AND COST OF ELECTRICITY

$10/gallon to $14/gallon, depending on the assumed price of electricity. It should be pointed out that actual electricity costs would be at least 12¢/kwh, and most probably higher, under circumstances that would lead to liquid fuel prices in excess of $10/gallon.

4.5.1.3 Cost of Battery Subsidy to the Government

It is proposed, for purposes of this discussion, that each vehicle operator receive a subsidy based on the following formula:

Subsidy ($) = Annualized Battery Cost + Annual Cost of Electricity for EV - Annual Cost of ICEV Fuel

The first cost term in the above will be assumed to be $1150, based on Table 4-4. The annual cost of electricity is assumed to be $200 based on 10,000 mi/yr vehicle use, 0.5 kwh/mi recharge electricity required per distance travelled and 4¢/kwh as the cost of electric energy. The annual cost of ICEV fuel will be based on the product of the fuel efficiency of a reference vehicle times the prevailing price of petroleum fuel. Both these items require further discussion.

The price of petroleum is the key variable in the proposed subsidy. For electric vehicles to be voluntarily accepted by the public given the economic obstacle that is presented by the cost of the battery, either the price of petroleum fuel has to increase significantly with regards to other forms of energy, or its availability has to be curtailed significantly, irrespective of its price.

The price of petroleum fuel has increased more rapidly than the rate of inflation since 1973. Since 1978, the wholesale price of gasoline has increased at an annual rate that is 30% higher than the producer price index on the cost of electricity. While it is unlikely that a compounded 30% annual increase in the constant dollar cost of petroleum will continue indefinitely, a compounded increase of 10% per year in the real cost of petroleum is not an unreasonable forecast.

The subsidy schedule for EV batteries presented in Table 4-5 was calculated on the above premises. At the start of the program, at the current price of petroleum fuel, the subsidy would be very high. In the first year, it would be equal to $1037 or 76.8 percent of the total cost of energy (battery and electricity) associated with the EV. As the price of petroleum fuel increased, the subsidy level would decrease annually until the 17th year when it would no longer be required. These values could vary if the constant dollar price of petroleum were to rise at a rate other than 10% per year. Such forecasts are beyond the scope of the present study.

The purpose of the subsidy is to have a potential automobile purchaser opt for an EV rather than an ICE vehicle of the same size class. The subsidy should be attractive enough for the purchaser to consider an EV instead of the most fuel efficient ICE vehicle in that size class. If the subsidy level is geared to the fuel costs of an ICE vehicle of average fuel efficiency, opting for a more fuel efficient ICEV instead of an EV would still be a more attractive economic option for the consumer. For purposes of the present discussion, fuel costs for an ICEV will be based on a vehicle fuel economy of 40 mgp, which is representative of the most fuel efficient sub-compact ICE vehicles on the road today.

It is recognized that the technology exists to significantly improve the fuel efficiency of sub-compact ICEVs, and that such vehicles may well be in production in the next decade. This would change the baseline which is used to establish subsidy levels. As ICE vehicle fuel economy increases, higher subsidy levels will be needed.

The cost of such a subsidy to the government would depend on the mechanism of the subsidy and on who was subsidized. Significant cost differences appear because of the differences in accounting procedures that would be applied to a commercial firm as compared to an individual.

A first mechanism would be to allow the owner of an EV to claim a tax credit every year for the additional energy costs associated with the operation of an EV. This tax credit would be applicable to both individuals and commercial firms that owned battery operated electric vehicles. The discounted annualized cost and total discounted cumulative cost of this support program is presented in Table 4-5.

A second approach would be to allow the owner of an EV a tax credit equal to 2.3 times the calculated annualized subsidy given in Table 4-5 in the year of purchase of the battery. This one time subsidy is based on a reduction in the annualized cost of battery ownership due to reduced interest foregone equal to 10 percent of the tax credit and in a lower depreciation equal to 33 percent of the tax credit.* The discounted annualized cost and total discounted cumulative cost of this support program are presented in Table 4-6.

A third approach would be to give a battery lessor a tax credit equal to

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* $2.3 = \frac{1}{0.43}$

TABLE 4-5 PROFORMA BATTERY SUBSIDY SCHEDULE (1980 Dollars)

Year	Price of Petroleum Fuel, \$/gal[a]	ICEV Fuel Cost, ¢/mi[b]	Break Even Annual Battery Subsidy		EV Population 10^3 vehicle/yr[e]	Annual Discounted Cost to the Government $\$10^6$[f]	Cumulative Discounted Cost to the Government $\$10^6$[f]
			\$[c]	as percent of electric energy cost[d]			
1	1.25	3.13	1037	76.8	8	7.54	7.5
2	1.38	3.43	1006	74.5	12	9.96	17.5
3	1.51	3.78	972	72.0	20	14.60	32.1
4	1.66	4.15	935	69.2	32	20.46	52.6
5	1.83	4.58	892	66.1	48	26.59	79.2
6	2.01	5.03	848	62.8	72	34.43	113.6
7	2.21	5.53	798	59.1	108	43.38	157.0
8	2.44	6.10	740	54.8	156	53.80	210.8
9	2.68	6.70	680	50.3	226	71.61	282.4
10	2.95	7.38	613	45.4	326	77.13	359.5
11	3.24	8.10	540	40.0	466	88.07	447.6
12	3.57	8.92	458	33.9	646	94.38	542.0
13	3.92	9.80	370	27.4	906	96.24	638.2
14	4.31	10.78	273	20.2	1240	89.03	727.2
15	4.75	11.88	163	12.1	1800	68.11	795.3
16	5.22	13.05	5	0.4	2500	2.74	798.1
17	5.74	14.35	-	-	3200	-	-

a) Based on \$1.25/gallon price of gasoline in Base year, and 10% annual constant dollar price escalation.

b) Based on 40 mpg ICEV fuel economy and gasoline fuel price given in Column 2.

c) Subsidy needed to obtain energy cost parity between EV and ICEV.

d) Battery subsidy as percent of annual energy cost of EV.

e) Population based on Figure 4-1

f) Discount rate of 10% per year assumed.

TABLE 4-6 - PROJECTED COST TO THE GOVERNMENT OF BATTERY PURCHASE SUBSIDY FOR EV OWNERS

Year	Annualized Battery Subsidy[a] $/Battery	Equivalent Battery Purchase Subsidy[b] $/Battery	Battery Sales, 10^3 c	Discounted Cost of Battery Purchase Subsidy to Government: Annual Cost[d] $\$10^6$	Cumulative Cost[e] $\$10^6$
1	1037	2412	8	17.4	17.4
2	1006	2340	4	7.7	25.1
3	972	2260	8	13.6	38.7
4	935	2174	20	17.8	56.5
5	892	2074	20	20.6	77.1
6	848	1972	32	26.7	103.8
7	798	1856	56	34.3	138.1
8	740	1721	68	38.5	176.6
9	680	1581	102	46.9	223.5
10	613	1426	156	55.0	278.5
11	540	1256	208	61.5	340.0
12	458	1065	282	61.2	401.2
13	370	860	408	59.7	460.9
14	273	635	544	56.8	517.7
15	163	374	714	39.5	557.6
16	5	12	996	1.5	559.1
17	-				

a) Based on Table 4-5

b) 2.2 x annualized subsidy, based on schedule given in Table 4-3 for individual owner.

c) Based on vehicle sale projections given in Figure 4-1, 12 year vehicle life end battery replacement after every 3 years during life of vehicle.

d) Product of previous 2 columns with a discount rate of 10% per year.

e) Discounted (10% per year) cumulative cost.

1.6 times the calculated annualized subsidy given in Table 4-4 in the year of purchase of the battery. The subsidy level is based on a reduced cost and profit associated with capital of risk with battery ownership because interest foregone is lowered by 10 percent of the tax credit, effective depreciation is reduced by 33 percent of the tax credit, and the profit required to maintain a 20 percent pretax return on investment is lowered by 20 percent of the tax credit.* It is assumed that general and administrative costs, while presented as a percentage of capital investment, would not actually change because a tax credit was applied. The discounted annualized cost and total discounted cumulative costs of this support program are presented in Table 4-7.

Of the three subsidy schemes presented, giving a tax credit to a battery lessor would result in a lower cost to the government than giving a tax credit to a vehicle owner, either for purchase of a battery or for using a battery in an EV. This follows because the lessor's costs were assumed to be proportional to the O.E.M. price of the battery, which was taken to be half of the retail price of a battery which was assumed to be the basis of cost for the operator of an EV.

Providing a tax credit to battery lessors would cost the government less than providing tax credits to individual vehicle operators. Administratively, many fewer parties would be involved. By the 16th year of such a program, one could envision 2.5 million EVs in operation (with a commensurate number of owners), but only about 50 battery leasing systems. It would be much easier to monitor and verify the purchase of batteries by 50 firms than by what may be more than one million individuals and firms. The government would also be in a position to monitor the leasing fees charged to vehicle operators. This function could be easily performed by existing audit agencies.

Giving a tax credit for the purchase of an EV battery rather than its use is less expensive mainly because interest foregone is significantly reduced. Administratively, it would be easier to monitor a subsidy based on purchase of a piece of equipment, rather than its operation. A tax credit against purchase would be a one time deal for which precedents already exist (i.e. such as conservation tax credits). A tax credit for operating a vehicle would require annual filing for the life of the battery. It would also establish an unusual precedent, apart from being more expensive.

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* $1.6 = \frac{1}{0.63}$

TABLE 4-7 - PROJECTED COST TO THE GOVERNMENT OF SUBSIDY TO BATTERY LESSORS

Year	Annualized Battery Subsidy[a] $/Battery/yr	Equivalent Battery Purchase Subsidy to Lessors $/battery	Batteries Acquired[c] 10^3	Discounted Cost of Subsidy to the Government: Annual Cost[d]	Discounted Cost of Subsidy to the Government: Cumulative Cost[e]
1	1037	1646	8	11.9	11.9
2	1006	1597	4	5.3	17.2
3	972	1543	8	9.3	26.5
4	935	1484	20	12.1	38.6
5	892	1416	20	14.1	52.7
6	848	1346	32	18.2	70.9
7	798	1267	56	23.4	94.3
8	740	1175	68	26.3	120.6
9	680	1079	102	32.0	152.6
10	613	973	156	37.5	190.1
11	540	857	208	42.0	232.1
12	458	727	282	41.8	273.9
13	370	587	408	40.7	314.6
14	273	433	544	38.9	353.5
15	163	259	714	27.2	380.7
16	5	8	996	1.0	381.7
17	-	-			

a) Based on Table 4-5

b) 1.6K annualized subsidy, based on schedule given in Table 4-3 for battery lessor

c) Based on vehicle sales projections given in Figure 4-1, ly year vehicle life and battery replacement after every 3 yeras during life of vehicle

d) Product of previous 2 columns, with a discount rate of 10% per year

e) Discounted (10% per year) cumulative cost

4.5.1.4 Potential Problems

Subsidizing battery lessors during the first years of the program would present a number of difficulties. First, prior to the seventh year, there will not be enough EVs in operation (according to this study's assumption) to support any battery leasing system. While one can argue that the creation of battery leasing systems could act as a spur for demand of EVs, and that the existence of a battery leasing system could accelerate the local demand for EVs, one can also argue that a battery leasing system would follow the initial growth of an EV fleet and would occur only when a critical mass level were attained. This argument points out a possible need for controlling the rate of introduction of exchange systems by licensing them as public utilities. If it were deemed necessary to license battery exchange stations, it would appear that this would be a responsibility of the individual states through their Public Utility Commissions rather than the Federal government. A consequence of such actions would be to give battery exchange stations a more local character, similar to the local electric companies, rather than a more homogeneous national character, a characteristic of current gasoline service stations.

A second difficulty of such a program is that, in the early years, the calculated tax credit given to a lessor to achieve energy cost parity between an EV and an ICE vehicle would be higher than the OEM price of the vehicle battery. Before the sixth year, the calculated tax credit would be higher than the assumed wholesale price of $1385 for the vehicle battery. The subsidy would have to carry both the cost of the battery and the cost of the operation. Such a program would be politically unacceptable. Under such circumstances, it would be better to consider the establishment of a "pilot" battery exchange program in the early years under the aegis of a federal contract. The program could be carried out under a cost sharing arrangement where in the government would carry most of the cost, either 80 or 90 percent. Such cost sharing arrangements have been characteristics of many prior programs established to demonstrate new technology. Such a program would not require 10 three bay stations, but would require at least five or six smaller stations to provide a sufficient geographic coverage. Such a pilot 3 or 4 year demonstration program would cost in excess of $50 million to cover operating and administrative costs for the duration of the program, as well as system and capital costs. It would establish the validity and usefulness of a battery exchange program with basis of real world experience. It would provide a clearly supervised environment where potential or heretofore unidentified problems associated with the concept could be identified and corrected.

In particular, there may be environmental hazards. These would result primarily from electrolyte spill and hydrogen evolution. The latter may not be a problem of significance since it may generally be addressed by providing forced ventilation in the recharging stations as specified by local codes. However, acid spills as the result of accidents may be more significant. While OSHA requirements for exchange station workers may be met by providing appropriate safety equipment, and waste water and sewage standards may be met by neutralization of waste water, the frequency rate of accidents in battery exchange may be an important factor.

If one uses the hypothetical 10 station network discussed previously, one concludes that, with an average of 2000 battery exchanges per day, this network performs almost 600,000 exchanges per year. Given an accident frequency of one in a million, the incidence of spills is not significant, while a frequency of 1 accident in 100,000 exchanges could result in 6 accidents per year. A high accident rate involving battery exchange could prompt prohibitive insurance premiums to cover claims against vehicle damage. Battery exchange (5 minutes to exchange a battery weighing about 300 kg to 500 kg (600-1000 pounds) must be devised as an essentially accident free procedure if this approach to range extension is to be realized.

Such a pilot demonstration program would also promote the development of a geographically concentrated fleet of electric vehicles which would also provide valuable operating data for many other insurance companies in terms of setting collision and liability rates for EVs.

If the pilot demonstration program was technically successful, the tax credits outlined in Table 4-7 would provide a strong incentive for the development of an EV battery leasing business. Combining tax credits with a 3 year depreciation schedule would allow battery lessors to write off their investment in two years or less, up to the 14th year of the outlined program, thus providing them with a good cash flow position.

It may be desirable during the initial years of commercialization of EV vehicles to consider the subsidization of the battery purchased by individual owners to provide the nuclei of fleets for future battery leasing/swapping systems. Whether an urban commuter would purchase an EV, even with a strong financial incentive, without having a range extension infrastructure available is an open issue. Such a subsidy would, however, provide a very strong incentive for fleet users who use their vehicles over predetermined or closely controlled routes. Vehicles in urban delivery fleets could perform their missions without the need for range extension facilities. A subsidy for EV batteries based on an ICEV fuel economy of 40 mpg would be extremely attractive to operators of light duty ICEV delivery vehicles that, because of their driving patterns, achieve fuel economies in use of less than 10 mpg (4-13). For such operators, a lower subsidy than that indicated in Table 4-5 might still be an effective incentive for the purchase of EVs.

An important factor in the calculation of the annualized cost of battery ownership is the depreciation rate. In the calculations performed in the prior section, the depreciation period was based on a three year battery life which is optimistic in light of current experience (4-14). Increasing the life of the battery would significantly decrease the cost of operating an EV. If the reliable life of the vehicle battery were to be doubled to six years, depreciation costs would be decreased by half to $228 /year or 2.3¢/mile based on OEM price, or $457/yr, or 4.6¢/mile, based on the assumed retail price of the battery used in the calculations. These costs differentials are equivalent, in the comparison with a 40 mpg sub-compact ICE vehicle, to an increase in the prices of petroleum fuel of $0.92/gallon and $1.84/gallon respectively. Doubling battery life to six years would reduce the annual cost of ownership for a battery lesor by 29 percent, and by 40 percent for an individual purchaser. Ideally, it would be desirable to increase the life of an EV battery to twelve years to match the projected life of the vehicle. Development of such a battery (assuming no change in acquisition price) would further reduce the cost of battery ownership by $114/yr, or 1.1¢/mile based on OEM price, or $200/year, or 2.5¢/mile, based on retail price.

These calculations indicate the importance of current DOE sponsored research and development programs to improve the operating and life characteristics of battery systems for vehicle use.

4.5.2 Transient Recharge

The rationale for transient recharge is that it represents a method of range extension for pure electric vehicles that would allow the development of a large fleet of EVs with existing technology. Such recharging facilities would be used to provide a partial recharge of the batteries any time the vehicle was parked. The effective range of present limited range EV, powered by

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(4-13) B. R. Herrow, J. W. Howe, and D. W. Humphreys, "State of the Art Assessment of In-Use Electric and Hybrid Vehicles, FY 1978," Report No. DOE/TIC - 10231, October 1979, p. 1-31.

(4-14) Loc. City Reference 4-13, Figure A-8, p. A-22.

state-of-the-art batteries, would become sufficient to attract a large consumer market. It was further claimed that providing infrastructure of recharging outlets would be simple and inexpensive.

As discussed in more detail in Chapter 3 the development of a large network of self-service recharging stations would present many problems which include:

a) A usage pattern involving principally daytime recharging
This would be counter-productive to the rationale behind the use of EVs in that it minimizes their petroleum conservation potential and aggravates load-management for utilities.

b) A very high cost per distance travelled. Because of relatively high fixed costs, the cost of recharging in transient stations is nearly independent of the amount of energy transferred.

This will discourage operators who had only driven short distances. Even for those operators who would have a significantly depleted battery, the cost of recharge would be such that the cost of the energy transferred in a transient recharge station would be significantly higher than the cost of the same energy transferred at a home base of operation during off-peak hours. The cost of energy transferred per distance travelled is, furthermore, very high in absolute terms.

c) Unknown safety and liability hazards. While transient recharge electrical hazards may be limited by separating the vehicle operator from the high voltage, high current circuit through state of the art conrol circuits, the use of such a power outlet at an unmanned parking lot, where they would be prone to vandalism, could raise many legal questions relating to the liability for any accident.

The disadvantages outlined above overweigh the claimed benefits that would be obtained from installing an extensive unmanned transient recharging stations. It is recommended that no positive action whatsoever be taken towards establishing such a network.

There would however be need for the establishment of a limited number of manned recharging stations that would provide emergency "life line" service, and which could justify the relatively high cost of recharge. Approximately one stall could be built for every 100 EVs in an area. At a cost of approximately $500 per recharge facility the investment would only be $5 per associated EV. Such facilities would be expected to be available at any EV dealership who could provide the initial "cadre" service.

Such "life-line" service could be encouraged by providing tax credits, similar to those provided for home base recharge, to businesses that installed emergency recharging facilities. However, to prevent unwarranted daytime recharging of electric vehicles, a stipulation of such subsidy aid would be that there be at least 100 EVs in operation within a finite area around the proposed recharging facility. Such support could last as long as that given for home base recharging. The cost of such subsidy would be approximately 1 percent of the cost of home base recharging support discussed in section 4.4.2.

4.5.3 Range Extension Hybrid

The use of a low horsepower ICE to operate in conjunction with an "electrical drive" results in a novel hybrid vehicle concept. If the vehicle is designed such that the ICE supports the electric drive and sustains vehicle cruising at highway speeds then one obtains a vehicle with state of the art batteries comparable in range capability to the present ICE. Such a design would permit intercity travel and would broaden the second car market base for pure electric to include some portion of the single car market.

There appear to be no additional institutional barriers to this type of hybrid over those inherent in the pure electric vehicle using home base recharging. Indeed, this hybrid essentially eliminates the need for creating a new service and refueling infrastructure, eliminating these as biases against the electric vehicle. Home recharging would suffice as a means of "electric refueling" and the presence of an ICE would reduce the occurrence and concommitant hazard of "out of fuel" situations.

The major drawbacks to the range extension hybrid are a reduction of the petroleum conservation potential as compared to an all battery EV of about 20 to 25 percent as outlined in Hamilton's companion study (4-10) and in increased technical complexity because of the dual power sources. However, because of the need for a smaller battery, a range extension hybrid could be less expensive than a comparable all battery EV.

There is an active hybrid vehicle development program currently under way under the sponsorship of the DOE and the management of the Jet Propulsion Laboratory (JPL). Phase I or the Near Term Hybrid Vehicle (NTHV) program consisted of mission analysis, performance specification and design trade-off studies leading to development and preliminary designs of hybrid passenger car vehicles. It involved four contractors competing for a single Phase II contract for the final design and fabrication of an integrated test vehicle. Phase I was completed in November 1979, at which time it was announced that the General Electric Company was selected as the Phase II contractor.

In terms of overcoming the institutional bias due to range extension, at least in the near term, the hybrid concept is much preferable to the other modes of range extension considered in this study in that the required refueling infrastructure already exists. There would be no need for government subsidies to promote a refueling infrastructure. While leasing of hybrid batteries is a possibility, an extensive network of swapping stations, which would represent a capital cost of a few hundred dollars per electric vehicle ($300 per vehicle in the specific example used) would not be required. In the longer term, if and when petroleum fuels were to become unavailable, the range extension capability of the ICE portion of a hybrid would disappear.

In the near term, continued R & D support of various hybrids using alternate operating strategies may be the most inexpensive Federal action that could be undertaken to overcome the obstacle of range extension for battery powered vehicles.

4.6 SOURCES OF FUNDS

The funds for EV subsidy programs would have to be generated from one of the following:

a) imposing an excise tax on the sale of ICE vehicles or on the sale of their components
b) imposing an excise tax on the operation of all automotive vehicles, with the potential exception of EHVs
c) imposing an excise tax on the sale of petroleum fuels for ICE vehicles
d) imposing a severance tax on the production of crude petroleum
e) drawing from general revenues

Given that a major policy objective of the EHV commercialization program is petroleum conservation, a rational argument can be made for imposing an excise tax on the purchase or operation (including the purchase of petroleum fuel) of ICE vehicles, and using the funds so generated to support the growth of a fledgling fleet of EHVs.

Since the number of ICEVs in operation would greatly outnumber the number of EHVs that would be subsidized, the cost to the owner-operator of an ICEV, even for a significant level of subsidy per EV, would not be high. Furthermore, to the extent operation of an ICEV is penalized, the subsidy level required to promote EVs is lowered. However, for political reasons outlined below, it is unlikely that Congress would support such a fund transfer, from operators of ICEVs to operator of EHVs, so that support for any EHV subsidy program would be likely to come from general revenues.

4.6.1 Imposing an Excise Tax on the Sale of ICE Vehicles or on the Sale of their Components

The Internal Revenue Code (26 USC) currently imposes a number of excise taxes on certain classes of highway motor vehicles and components. Sections 4061(a) and 4063(a)(6) specify an excise tax of 10 percent on the sale of automotive highway vehicles with a gross vehicle weight greater than 10,000 lbs, and of 8 percent on the sale of parts for these vehicles. Based on P.L. 95-599, these excises will be reduced to 5 percent on and after October 1, 1984.

Code Sections 4071 and 4218(b) specify an excise tax of 10¢/lb for tires and inner tubes for highway vehicles, and lower taxes for other rubber products and for tires destined for non-highway use. These taxes will be reduced to 5¢/lb for highway tires, and to 9¢/lb for inner tubes, on and after October 1, 1984.

Section 4064 imposes a gas guzzler-tax on passenger automobiles of low fuel economy. In model year 1980 vehicles with a fuel economy greater than 15 mpg were not taxed. Automobiles with a fuel economy of less than 15 mpg were taxed on a sliding scale that ranged from $200 for vehicles with a fuel economy between 14 mpg and 15 mpg, to $550 for vehicles with a fuel economy of less than 13 mpg. In model year 1981, automobiles had to attain a fuel of at least 17 mpg to avoid this tax. For vehicles with a fuel economy of less than 17 mpg, the tax ranges from $200 for vehicles with a fuel economy between 16 mpg and 17 mpg, to a maximum of $680 for vehicles with less than 13 mpg. These levels increase progressively with each consecutive model year up to model year 1986. 1986 automobiles will have to have a fuel economy greater than 23.5 mpg for the tax not to be imposed. In 1986, the gas guzzler tax would range from $500 for a vehicle with a fuel economy of between 22.5 mpg and 23.5 mpg, to $3850 for a vehicle with a fuel economy of less than 12.5 mpg.

While the above are precedents for imposing a federal excise tax on transportation vehicles and their components, it is unlikely that Congress would enact any new tax that would be applied against the American automobile industry given the industry's present financial difficulties. Passage of any excise tax on personal transportation vehicles would become politically feasible only when, and if, the American automotive manufacturers became profitable again on a sustained basis.

It could be argued that the funds generated from gas guzzler taxes be used to support petroleum conservation programs in the transportation field. The difficulty with this argument is that the gas guzzler tax was enacted to be a barrier to the production of fuel inefficient automobiles, rather than as a source of revenue. It is likely that manufacturers will sell few (if any) automobiles in the U.S. that will be subject to this tax and that the levels of funds generated by this tax will be small and not assured.

4.6.2 Imposing an Excise Tax on the Operation of all Automotive Vehicles, with the Potential Exceptions of EHVs

Sections 4481-4484 impose an annual highway use tax of $3.00 per 1000 lbs (or fraction thereof) of gross vehicle weight on all highway vehicles with a gross vehicle weight rating greater than 26,000 lbs. This tax rate will be eliminated on October 1, 1984.

There is no similar federal tax on passenger automobiles. Passage of such a federal excise is unlikely because the registration and taxation of automobiles is a well established right of the individual states, who would not look with much favor on the federal government imposing a tax competitive with major sources of state revenue. Furthermore, the administration of such a tax would not be feasible without the support of the individual states. Without the cooperation of the state motor vehicle departments, the federal government would have to develop a Federal Automotive Registration Office which would issue federal licenses, separate from the state licenses, to the more than one hundred million automobiles registered in this country. This is patently unfeasible and inefficient. With the cooperation of the states, the state automotive registration fee could be increased to include a federal highway use tax, which could then be transferred from the individual state treasuries to the federal treasury. The major objection to such a tax is that it is unlikely that the individual automobile owner would distinguish between the state and federal impacts when registering a vehicle, and such a federal tax would restrict the state's ability to increase their own automotive licensing fees if they cared to do so.

4.6.3 Imposition of an Excise Tax on the Sale of Petroleum Fuel for ICE Vehicles

Sections 4081 and 4082 of the Internal Revenue Code (26USC) impose a tax of 4¢ per gallon on gasoline (meaning "all products commonly or commercially known or sold as gasoline which are suitable for use as a motor fuel"). Section 4041 imposes a similar tax on diesel fuels for highway vehicles and for special motor fuels that are not taxed otherwise under Sections 4081 and 4082. Section 6421 exempts from the excise tax gasoline used for local transit purposes. The taxes are scheduled to be reduced to 1 1/2 ¢/gallon on or after October 1, 1984. Section 4081(c) provides that the 4¢/gallon federal excise tax is not to be imposed on the sale of any gasoline in a mixture with alcohol or upon gasoline for use in producing a mixture at least 10 percent of which is alcohol ("gasohol"). Alcohol is defined as including methanol and ethanol but does not include alcohol produced from petroleum, natural gas or coal. This exemption applies to sales or use of gasohol before October 1, 1992.

The rationale for the petroleum fuel tax is that it provides an equitable means of sharing the costs of building and maintaining the highway system used by road vehicles (thus the exemptions for fuels for farm and other off-highway vehicles). The rationale for the exemption given "gasohol" is that it provides a very strong financial incentive for the production of biomass derived alcohol, and promotes the development of an industrial infrastructure to provide a domestic alternate that could reduce transportation petroleum fuel consumption. Potentially, complete replacement of gasoline (or diesel) by "gasohol" could reduce transportation petroleum consumption by 10 percent. However this would eliminate the major source of support of the Highway Trust Fund.

The current federal excise taxes on petroleum highway fuels generate approximately $5 billion per year of revenue, based on current automotive consumption of petroleum fuels of 1.2×10^{12} gallons/year. Based on this consumption level, an increase in the fuel excise tax of 0.5¢/gallon (0.1¢/liter) would generate $600 million/year, which would result in the accumulation of $5.1 billion, discounted at 10 percent/year, over twenty years. This level of support would be more than ample to support the most generous of the incentive programs described above, even if there were a significant (e.g. 20 percent) reduction in use of petroleum for automotive vehicles.

All recent attempts at increasing existing gasoline taxes have failed to obtain Congressional approval. This is unlikely to change. As long as this philosophy persists, this option cannot be considered as a likely funding source. However, if a significant (i.e. of the order of $0.50/gallon or more) deterent tax on automotive petroleum fuel were to be enacted, support for the commercialization of electric vehicles could be obtained from the funds so generated.

4.6.4 Imposing a Severance Tax on the Production of Crude Petroleum

The Crude Oil Windfall Profit Tax Act of 1980 imposes, effective March 1, 1980, a tax on all production of domestic crude oil after February 29, 1980. Although called a tax on profits, the tax is a temporary excise or severance tax on production, imposed at the wellhead as each barrel of oil is removed from the ground and sold. The tax is imposed on the holder of the economic interest in the oil, called the "producer" under the Act. Primary collection responsibility, however, is on the first purchaser of the crude oil.

Imposition of the tax resulted in large part from a Presidential decision to phase out the mandatory crude oil price controls over the period June 1, 1979 through September 30, 1981, and from the drastic increase in price of imported oil produced by OPEC member nations. Congress designed the tax to raise $227.3 billion in tax revenues over the period the tax is in effect. If the targeted amount of revenue is generated prior to or in December 1978, then a 33-month gradual phaseout of the tax will begin in January 1988. However, the phaseout will begin no later than January 1991, regardless of the amount of revenues collected.

Title II of the Act provides for a number of energy conservation production incentives for individuals and businesses. Incentives to individuals include extension of 15 percent tax credits on the first $2000 of expenditures on energy conservation measures applied to buildings constructed before April 20, 1977 (Sect. 201). It increases, for tax years after 1979, the tax credit on solar, geothermal and wind energy property to 40 percent of the first $10,000 invested in a principal residence (Sect. 202).

Under the general business energy investment tax credit provisions of Section 221 of the Act, a tax payer may obtain a 10 to 15 percent energy investment tax credit for investment in certain energy property, such as solar, wind or geothermal property, ocean thermal property, small scale hydroelectric plants, intercity buses, and biomass property. These tax credits can be applied in addition to investment tax credits that would be otherwise applicable until December 31, 1985.

While the Windfall Profit Tax provides for incentives for a wide range of energy conservation and alternate fuel production measures (including gasohol), no mention is made of fuel efficient automobiles nor of automobiles that would use non-petroleum fuels, such as EVs. Extending the tax credits now applicable to renewable energy source expenditures for primary residences to the purchase of an EV or the installation of EV home base recharging facilities, or applying business property tax credits to battery lessors, would be within the spirit and intent of Title II of the Windfall Profit Tax. The law would have to be amended accordingly. However, even if such an amendment to the Act could be passed, it is doubtful whether the tax credit levels of 10 to 15 percent currently applicable to other energy conservation business property would be sufficient to attract potential battery lessors, especially during the early years. A tax credit to individuals comparable to the 40% credit for renewable energy sources, if only applied to the purchase of batteries or the installation of recharging equipment, would not be a sufficiently high incentive for the purchase of an EV. However, such a credit would be sufficient if it were applied to the combined purchase price of the electric or hybrid vehicle, the initial battery pack and the replacement batteries.

APPENDIX A

PRELIMINARY ANALYSIS OF POSSIBLE ACTIONS/OPTIONS TO MINIMIZE OR ELIMINATE INSTITUTIONAL BIASES AGAINST ELECTRIC AND HYBRID VEHICLES

TABLE A-1. PRELIMINARY ANALYSIS OF POSSIBLE ACTIONS/OPTIONS TO MINIMIZE OR ELIMINATE INSTITUTIONAL BIASES AGAINST ELECTRIC AND HYBRID VEHICLES

INSTITUTIONAL FACTOR	RELEVANT VEHICLE CHARACTERISTICS	PRINCIPAL BIAS IMPACTS (+) Favors Electric (-) Against Electric +	-	MEASURED VALUE	COMMENTS	POSSIBLE CORRECTIVE ACTIONS/OPTIONS	OPTION LEVEL	DISCUSSION
1. Taxes and Regulations								
A. Federal Laws and Regulations								
1. Excise Tax								
a. Fuel Tax	Fuel, Fuel Economy	x		Tax of 1¢/l (4¢/gallon) Annual cost for study vehicle is - $5 to $22 (10,000 miles); 17 km/l (41 MPG) is $9.76	It appears unlikely that E.V.'s would be able to avoid an equal tax if their market penetration is substantial	Increased taxes on Petroleum Fuels to achieve parity in vehicle operating costs; to act as an incentive against petroleum based vehicles. (Note: an examination of gasohol support is an example of an incentive in support of an alternate source.)	1B	Federal taxes on petroleum fuel correspond to less than 1% of total operating cost of light duty ICEVs. Based on an ICEV fuel economy of 40 mpg, price of gasoline would have to be $6.00/gallon to achieve cost parity between ICEV and EV with electrical energy consumption of 0.5 kWh/mi, assuming a purchase price of electricity of 7¢/kWh. It is most unlikely that a gasoline tax of more than $4.00/gallon could be mandated into law. It should be noted that there has been resistance towards raising the existing 4¢/gallon tax, even though decreasing petroleum fuel consumption and inflation have made major inroads in the value of the financial support for the Highway Trust Fund.

Note: First four columns(Institutional Factor, Relevant Vehicle Characteristic, Principal Bias Impacts, and Comments) were developed in, and obtained from, DOE Report No. HCP/M1043-01, "Institutional Factors in Transportation Systems and their Potential for Bias Toward Vehicles of Particular Characteristics", Prepared by Transportation Systems Center, U.S. Department of Transportation, Cambridge, MA, December 1977.

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b. Lubricating Oil Tax	Power Plant	x		Tax of 1.6¢/l (6¢/gallon)-Annual cost for study vehicles is ⊄ 10¢ to 40¢ fuel tax) 17¢	This is a negligible bias against ICE's.			
c. Tires and Tubes Tax			x	Tax of 4.5¢/kg (10¢/lb) on rubber	This is a negligible bias against E.V.'s since they require bigger tires	Impose an excise tax on ICEV's similar to that on tires and tubes and truck parts	IB	Politically difficult to accomplish. Would face major opposition by automobile manufacturers and labor groups.
2. Income Tax Deduction	Fuel, Fuel Economy, Fair Market Value		x	Lessens bias against ICE brought about by state and local taxes on property and fuels	The effects of these laws depend on the itemizing of deductions and the respective income bracket	Income Tax Deductions or Tax Credits could be used to offset higher initial purchase costs and/or higher operating expenses	2B	Indirect Federal subsidy for EHV. Impact on Consumer and Federal Revenues would depend on level of subsidy. (see studies on subsidy analysis by MATHTEC (Sept. 77)
3. Customs and Tariffs				None	There appears to be no bias for or against specific vehicles other than those provisions incorporated under other federal laws and regulations			

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4. Safety Standards	Crashworthiness		x	Due to different weight propagation factors (ICE = 145; E.V. = 1.75) the addition of safety standards equipment is favorable to ICE, i.e. the addition of 45 kg (100 lbs) of equipment to E.V. results in 34 kg (75 lb) propagated weight and $160 price increased. The same equipment on an ICE results in 20 kg (45 lb) propagated weight and $30 increase	Data concerning the required total weight increase is not readily available. Only available source is a 1974 Ford Study which shows that the conversion of an ICE vehicle (Pinto and Comet) into an E.V. would require an increase of 91-204 kg (200-450 lbs) due to safety standards. The results of the report however, are not applicable to a new-design E.V. and are inflated due to the fact that they anticipate changing federal standards	1) Relax standards for EHV's commensurate with their more modest operating characteristics	1B	Not politically feasible, necessary to establish common standards to all vehicles on the road. Would offset incentives to reinsurance through adherance to standards by EHV's
						2) Relax standards for all vehicles	1B	Would require revamping of policy developed over past 20 yrs Overall sociatal costs in terms of traffic accident fatalities would be higher than justifiable from improved fuel economy.
						3) Support R&D of High Strength/Weight Materials for automotive structures	2C	Development of lightweight auto structures would be beneficial to both ICE and EHV's, but would result in greater marginal benefits for EHV's because of differential weight propagation. Other than for one program on lightweight components (JPL/Budd) very little is being done in this area. Use of graphite composites can be justified more easily in EV's than ICE's High Probability of Tech success Politically feasible action.

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5. Air Pollution Control	Emissions ($HC/CO/NO_x$)	x		First cost, fuel costs, maintenance cost. Depending on emission level implemented costs are 0.2 to 0.6¢/km (2%-5% of life cycle costs of ICE study vehicles)		1) Lower Emission Standards for ICE to less than 0.41/3.4/0.4	1B	Politically unfeasible. May not be technically feasible either. This would be effectively a ban on ICE's, and would have little chance of favorable congressional action.
						2) Exclude EHV's from bans on auto usage in Regional Transportation Control Plans as now written	2B	Would allow EV's to operate in an environmental emergency when ICE's were banned. This could be accomplished fairly easily, possibly by EPA regulation without requiring passage of legislation. Impact on EHV sales would be probably small since transportation bans have not yet been put into effect. After establishment of first ban, this would result in promotion of EHV as alternate transportation mode however, only if power plant emissions are not curtailed during the environmental emergency.
6. Noise Control	Power Plant Noise				Not applicable to vehicles under 10,000 lbs			

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7. Energy Policy and Conservation Act	Fuel Economy	x			Bias for E.V.'s under President's Standby authority to ration petroleum fuels. Otherwise no bias since all study ICE vehicles surpass Act-specified fuel economies Modification of Electric and Hybrid Vehicle RD &D Act which calls for inclusion of EHV's in an auto manufacturer's CAFE at a favorable equivalent petroleum fuel economy is very favorable to EHV's.	1) Implement Rationing of Petroleum Fuel	IC	Limiting availability of petroleum fuel make EHV a more effective form of transportation Rationing of petroleum in absence of identifiable national emergency would be difficult to implement.
8. Emergency Policy and Conservation Act	Fuel Economy		x	Price of Gasoline	With decontrol of petroleum prices by Executive Order in April 1979, and subsequent passage of the Crude Oil Windfall Profits Tax Act, this is no longer an issue.			

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9. Rural Electrification Act	Electrical Equipment	x		Vehicle first cost derived from low interest loans (2%) available under the Act	If applicable, REA provisions for financing the initial purchase of an electric van would reduce the net present value of the life cycle cost by 8%-12% for an electric van (as compared to outright purchase)	1) Determination by Administrator of REA that EHV's are applicable under the RE ACT. If favorable ruling obtained, major action required would be:	2B	Statuatory mechanisms already exists.
						a) Publicity to inform RE Company's and their customers of the applicability of the Act to EHV's and of benefits to farmers to be derived from agricultural use of EHV's	2C	If a viable EV van were to exist, this provision could be effective means of promoting sales of approximately 70,000 units/year, especially if this incentive was in addition to other incentives. In terms of operation, fewer obstacles exist on a farm than in an urban environment. Vehicle range and payload would be significant requirements.

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B. State Laws and Regulations								
1. Registration and Licensing fees	Varies according to individual state regulations. In some cases, fees are based on horsepower, passenger capacity, form of fuel				In most states, fees are neutral in respect to E.V.'s. In some states biases appear split between favorable and unfavorable provisions. The unfavorable provisions are attempts to recover revenues lost due to the absence of an applicable fuel tax.			
2. Fuel Tax	Fuel, Fuel Economy	x		Tax ranges from 5¢-11¢ - Annual cost for study vehicle is -$6 to $60	It appears unlikely that E.V. would be able to avoid an equal tax if their market penetration is substantial	Increase Tax on Petroleum Fuels	1B	See Section IA1a - Federal Fuel Excise Taxes Furthermore Revenue derived from Motor Fuel Taxes would have to be examined in terms of sensitivity of gasoline sales to gasoline price, and impact of change in revenue level to states with varying gasoline prices, and penetration of EHV's. If there was a reduction in revenue, how would this impact road maintenance? If there was a surplus how would the money be justified and spent?

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3. Income Tax Deductions	Fuel, Fuel Economy		x	Lessens bias against ICE'S brought about by state and local taxes on fuels	Particulars vary according to individual states	Income Tax deductions or Tax Credits could be used to offset higher initial costs or operating expenses	2B	Indirect State Subsidy for EHVs see section IA2
4. Sales Tax								
a. First Cost	Retail Value		x	Tax of 4%-6% in four test states - due to higher acquisition cost of E.V.'s the buyer of an E.V. might pay $34-$240 more in first cost sales tax		Make EV or EHV's exempt from State Taxes	1B	Politically unlikely, would have little impact on vehicle sales.
						Federal govt. gives EHV buyer tax credit equal to sales tax differential	2B	Requires revision of tax law. May have little impact on sales of EHV's.
b. Life Cycle Cost	Retail value, parts and materials for maintenance (this includes battery)		x	Annual ownership cost for E.V. owners is $11-$52 more than ICE				
5. Property Tax	Fair Market Value		x	Average annual tax for E.V.'s is $3-$66 more than ICE tax depending on tax rate	Bias against E.V.'s due to the fact that assessed value is greater. Amount of tax depends on assessed value and tax rate	Federal government (or state government) gives EHV buyer tax credit equal to property tax differential	2B	Requires revision of tax law. May have little impact on sales of BHV's
6. Utility Tax	Fuel, km/kw (Energy Economy)		x	Cost of electricity	Small bias against E.V.s			
7. Noise Control	Power Plant Noise	x		Price of Muffler and Exhaust System	Slight bias against ICE - Easily rectifiable through the use of noise control system.			

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8. Miscellaneous Regulation								
a. Discretionary Safety Laws	Speed, Gradeability, Acceleration		x		Potential bias against E.V.'s due to the existence of regulations which, if applied, might exclude E.V. from some highway travel (i.e. high speed and/or hilly) as a result of their inability to maintain speed comparable to the average speed			See Highway Traffic Control Below
b. Insurance Laws	Fair Market Value. Crashworthiness, Damageability, Theft Rate Third Party Damage		x		Potential bias against E.V's due to the possibility that insurance rates will be higher - or even unavailable - given the uncertain E.V. accident and theft related costs	Federal Government to act as insurer, or reinsurer, for all vehicles and drivers.	1B	May be important in liability area
						Develop statistically significant data base by having large pilot fleet of EHV's on the road	2C	Same cause of bias exists in other areas, such as consumer loans for EHV's, manufacturer's liability risk, manufacturer's business risk.
						Option 1 Fed Agencies maximize their purchase of EHV's	2C	emphasized Sect. 11 of PL 94-413 Alter current procurement practices which emphasize first costs rather than life cycle costs, and current six year replacement practice. Govt. currently purchases approx. 70,000 vehicles/year.
						Option 2 EHV's integrated into UMTA programs	2C	Fed govt. currently pays 80% of urban buses. Could apply similar benefits to EV buses so that they would not cost a municipality more to purchase than ICE buses. EV vans may be particularly useful to minivans for feeder routes, or as jitneys - range may be problematical

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						Option 3	Major govt. contractors required to purchase EHV's in significant numbers	0-1C	Difficult to accomplish - may be illegal.
						Option 4	Regulated Utilities required to purchase EHV's in significant numbers	1A-2A	Regulated utilities, especially power companies, have already much to gain if EHV's are used. This group has shown significant interest in the use of EHV's. Regulation would not accomplish anything of use.
						Option 5	EHV's made economically more attractive to the consumer		
							a) subsidy	1C	Difficult to accomplish and expensive (see Prior DOE analysis)
							b) tax credit	1B-2B	Similar to Sales Tax, but more difficult to accomplish because of higher dollar value.
							c) Impose excise tax on ICEV	1B	Politically difficult to accomplish - see prior section on Fed excise taxes
							d) raise gasoline taxes significantly	1B	Politically difficult to accomplish - see prior section on Fed excise taxes

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II TRAFFIC CONTROL								
A. Highway Traffic								
1. Speed Laws	Maximum Speed, Acceleration, Gradeability		x	Increase to accident involvement rate.	In high speed road use the interaction between vehicle characteristics and highway grades causes E.V. performance measurably lower than ICE's at the average highway speed resulting in greater accident involvement rate	1. Eliminate or significantly lower minimum speed laws and other regulations that would exclude slow moving EHV's from highways, while: a) not changing maximum speed limit or b) significantly lowering maximum speed limit	0	1a. This option would be difficult to justify, would result in a dangerous mix of fast and slow moving vehicles on the highways which would increase the accident rate 1b lowering the speed limit would be difficult to accomplish without the existence of an obvious national emergency that would place a premium on fuel economy
2. Access Ramps	Acceleration, Gradeability		x	Ability to enter high speed traffic: given ramp dimensions of 4%-6% grade and 213-304.8 m(700-1000 feet) length; minimum required entry speed of 64 km/h (40 MPH); it would appear that E.V.'s can not utilize acceleration ramp	This is a substantial bias against E.V.'s especially if the following factors are considered: -Given the 1000 feet length of ramp the 2 pax E.V. and E.V. van would be unable to negotiate even a 1% grade -Limitations on ramp usage might still be manageable if, by using a 2-3 km detour, the driver could use a depressed or at-grade entrance point.	2. Encourage stricter enforcement of 55 mph through education, threats (highway trust fund), allocation of funds to increase highway police	2C	This would lower speeds at which ICEV's are now operating on highways, and decrease discrepancy in relative velocities of EV's and ICEV's. The impact on EV sales is expected to be small
						3. Increase Performance characteristics of EHVs a) Increase Federal R&D Funds	2C	Allocate greater resources to EV Related R&D. How much additional progress would be obtained with added funding of advanced batteries, advanced structures and more efficient components.

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					Indications are, however, that this is not the case -At the average highway speed of 88 km/h (55 MPH) the entering speed of 64 km/h (40 MPH) would result in an accident involvement rate three times higher than entering 88 km/h at (55 MPH). Proportionately, at the average highway speed of 105 km/h (54 MPH) this rate would be 14 times higher	b) Give Mfgrs tax credits for private R&D on EHV related technology.	1B	Encourage manufacturers to allocate more of own funds to the development of proprietary R&D related to EHV's. May be more applicable to large manufacturers than small ones, including R&D firms. Control of expenses would be problem.
						4.0 Rebuild highways to eliminate hills and steep ramps.	0	Not feasible
B. Traffic Light Timing								
1. Fixed-Time Signals	Size, Acceleration			Intersection capacity; no significant effect	The effects of slower acceleration are generally offset by smaller size	1) Reset traffic signal timing as required	2A	Minor bias, minor correction, minor effect overall
2. Demand-Actuated Signals	Size, Acceleration			Intersection capacity, no significant effect	Even in all small car traffic pattern, where E.V.'s could theoretically reduce the flow by 5%-15%, the problem can be alleviated by resetting the signals.			
3. Travel Time	Acceleration, Size			Travel time: no significant effect	For E.V.'s with acceleration of 4.3 km/h/sec (2.7 MPH/sec.) independent from other traffic			

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INSTITUTIONAL FACTOR	RELEVANT VEHICLE CHARACTERISTICS	PRINCIPAL BIAS IMPACTS (+) Favors Electric (-) Against Electric +	-	MEASURED VALUE	COMMENTS	POSSIBLE CORRECTIVE ACTIONS/OPTIONS	OPTION LEVEL	DISCUSSION
					the travel time for a 8 km (5 mile) stretch is 4%-9% longer than for ICE with 8 km/h/sec. (5.0 MPH/sec.). The variation is due to the number of stops. For E.V. mixed with other traffic the difference is closer to the lower limit. Furthermore, signal timing could be adjusted to accommodate E.V.'s.			
C. Preferential Access Lanes (Car Pools)	Size (passenger Capacity)			E.V. qualifications as car-pooling vehicle; no bias against E.V. if definition of car-pool is 2 passengers. If definition is 3 passengers then there exists a prohibitive bias against 2 pax E.V. and a potential, but unquantified bias against 4 pax E.V.s	The potential bias against 4 pax E.V.'s is theoretically due to the possible unwillingness of commuters to travel in groups of 3 or more in a car similar in size to an ICE subcompact	1) Allow EHV's with one or two passengers in preferential access lanes	1B-2B	If car pool lanes become more prevalent, this could result in a favorable bias that could impact EHV sales favorably since this action would have effect of reducing commuting time for 1 or 2 passenger vehicles. One passenger "car pool" might be difficult concept to sell. Two passenger minimum would be more rational.
(Other)	Speed & Acceleration	x		Reserved lanes for low performance vehicles		2) Extend concept of low speed travel lanes to wider group of vehicles, including EV's, bicycles mopeds, et al.	2 B	Would detract from role of EHV as a viable alternative to current ICEV's. Would be expensive to implement

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D. Vehicle Segregation Policy	Size (Width)		x	Street capacity for traffic flow: the sizing of some streets for small car use can increase capacity by temporarily deleting parking lanes and adding traffic lanes	Existing urban design and congestion patterns indicate that traffic flow can be greatly improved through the use of smaller cars. The deletion of parking lanes in large car traffic is not as efficient.	1) Reduce width of traffic lanes	0	Questionable effect since truck traffic also has to be accommodated. Impact on EHV's would be small.
E. Tolls and Congestion Pricing	Size (Passenger Capacity)			Qualifications for multi-passenger vehicle	A bias against E.V.'s might exist if pricing depended on passenger occupancy (see preferential access lanes)			See discussion on preferential access lanes above
III. URBAN-DESIGN								
A. Urban Density	Multifunctional Capability	x	x	1. Car ownership - multi-car ownership is inversely proportional to urban density	Extreme urban density is a bias against E.V. to the extent that E.V.'s are more suitable to multi-car households	1. Increase multi-functional capability of E.H.V.'s, improve E.H.V. technology level by supporting R&D	1C-2C	See page 11 on R&D
	Range	x	x	2. Trip length - proximity of work, shopping, and home	To the extent that trip lengths are beyond the E.V. range low density settlement is a bias against E.V.	Increase Range of EHV's Improve EHV's technology level by supporting R&D	2C	See page 11 on R&D. Emphasis could be on hybrid vehicles rather than EVs to accomplish the missions.
	Range	x	x	3. Commercial vehicles stem trip length	In high density areas E.V. vans are not excluded from pick-up and delivery operations by range alone.			

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B. Intermodal Planning	Range		x	Automobile segment of home to work tirp	Insufficient intermodal facilities planning (i.e. Park and Ride and Van Pool) creates unnecessarily long automobile segment of home to work trip	Promote Intermodal Facilities to decrease auto segment of home to work trip	IC	
C. Access Policies	Noise and Emissions		x	Accessibility of some urban areas to E.V.	Indiscriminate application of policies designed to minimize urban pollution from automobiles would create an unnecessary bias against E.V.'s	Specifically exclude EHVs from bans on automobiles in urban areas	2B	See page 4, Section 1A5
D. Parking Supply								
1. Commercial	Size		x	Apportionment of parking fees - 30% reduction in parking fees for small cars is possible	This is a potential bias against small cars	Promote establishment of rate schedule that varies with certain size	2B	This sort of action is accomplished in NYC where differential rates for small/large cars exist in manned garages (i.e. where the garage owner parks the car) in unmanned garages, this would require separate areas for large & small cars. This increases administrative costs of garage operation, and may result in less than full utilization of garage space. To max. use, garage has to be designed to be large car limited; some small cars go in large slots.

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2. On Street	Size		x	Apportionment of parking fees - 30% reduction in parking fees-potential for 30% increase in parking facilities through small car sizing	This is a potential bias against small cars	Promote separate parking areas for large and small cars	2B	Feasible option in design is large car limited. Rates would have to be set so that small car slots slightly less expensive than large car slots so that small cars would have to use their slots
3. Residential	Recharging Requirements		x	Off-street parking facilities and electrical outlets. 60% of households do not live in single-family houses with covered parking	Recharging of batteries is easiest in residential covered parking situations However, required data on uncovered off-street parking, multi-family parking and relative difficulties of home recharging situations is not available	1) Promote Housing Codes that require off-street parking facilities in multi-family dwellings	2A	This is already in effect in many municipalities in terms of new construction.
						2) Promote Housing codes that require electric outlets suitable for recharging EHVs wth offstreet parking	1B	
						3) Promote public parking recharging facilities	1C	
E. Covered/ Uncovered Parking Famlilities	Emissions	x		Cost of ventilation equipment is less than 7% of CBD covered garage costs	Insignificant bias			

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IV ELECTRIC SUPPLY								
A. Electric Utility Industry								
1. Capital Intensity	Fuel, Fuel economy		x	Price charged for industry's product	This is a small bias against E.V.'s since fuel costs constitute a small part of vehicle life-cycle costs. Major increase in price of electricity will have little impact.	Provide special rates for EV recharging by Federal Utilities	1B	Difficult to justify unless coupled with time of day re-charging to maximize utilization of power generating plant.
			x	Effect of demand on supply due to E.V.s 10 million E.V.'s (1995) would constitute only 2% of demand	The significance of potential capacity shortfalls appears limited	Promote off-peak recharging of EHVs under PURPA	2C	Institutional mechanism already in effect.
2. Government Regulations				Impact of laws on fuel availability and price	Government regulations could be interpreted to create a bias against E.V.'s by retarding generating capacity expansion, increasing the cost of new capacity, reinforcing high capital requirements, and increasing uncertainty in planning.	Relax environmental requirements on siting of new power plants.	1B	Would require reevaluation of philosophy developed by the Federal government over the past two decades.

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3. Rates and Pricing Policies	Fuel, Fuel Economy	x	x	Regional and time-of-day pricing effects on E.V.'s. Based on regional variations in E.V. could cost $130/yr in N.Y., $20/yr in Seattle (4 pax EV)	The variations in regional pricing might have a negative bias against E.V. since higher prices occur in densely populated urban areas.	Promote use of EHVs and site demonstration programs under EHV RD&D Act in areas most favorable to EHVs.	2C	Structure demonstration program to take advantage of favorable economic conditions for EHVs.
					Peak load pricing policies might create a positive bias on E.V.'s by allowing owners to recharge at night at much lower prices.	Include EHVs under PURPA	2B	mechanisms already exist to accomplish this.
B. Electricity Distribution	Recharging cycle							See P. 16, Sect. IIID3
1. Recharge at Home	(See Urban Design Section)							
2. Rapid Recharge/Battery Exchange Service	Recharging Cycle, Range		x	Availability and potentials of recharging stations	The lack of recharging infrastructure is a bias against E.V. This bias re-emphasizes the use of private facilities. The bias is further enhanced by the availability of electric power for individual recharging needs. Since there appears to be no institutional bias against recharging stations, the development of a recharging infrastructure is quite possible. The factors to be considered, however, are: the implications of rapid charging and battery exchange	1) Build network of EV rechargins stations available to the public.	1C	The lack of a recharging infrastructure is a bias against E.V. Significant further analysis to define options and possible policy actions is needed. This is a critical issue that has not been emphasized sufficiently in the past.
						2) Build network of Battery Exchange Stations and supporting recharging facilties	1C	

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V. FEDERAL POLICIES AND PROGRAMS: A. Energy Research Development and Demonstration 1. Federal Energy RD&D								
a. Electric and Hybrid Vehicle Research Develop. and Demonstration Act	All	x		Current planned expenditures are $160 million over the next five years	Short term demonstration could speed up the introduction of E.V.'s. On the other hand, the emphasis on short-term demonstration could hurt a sustained research and development effort if initial results are disappointing.	1) Increase level of funding for EHV's under EVRDD Act	1C	It would be necessary to justify how added expenditures would accelerate the development of EHV's. Is the development of the technology being pursued at a substantial funding rate? Would greater funding result in better batteries and components, sooner (Research)? Would more money result in better implementation of existing technology (development)? Should the govt. increase the size of the purchased demonstration fleet to provide a more comprehensive pilot experiment for EHV's? Should the scope of the EHV RDD Act include establishment of recharging stations and maintenance stations? Politically it may be difficult to pass in view of close fight on existing act.

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b. Research in Alternative Energy Sources	Fuel	x		Current RD&D funds for electricity eneration are $1,741 millions compared with $106 millions for synthetic gaseous fuels and $95.3 millions for synthetic liquid fuels	Emphasis on electricity generation is due to the following factors: - electricity generation currently accounts for 25% of U.S. primary energy consumption and is growing rapidly. -conversion to alternative fuels for the generation of electricity can produce sizable short-term savings. -Some of the nation's abundant energy sources (e.g.nuclear) can achieve widespread use only with electricity as the intermediate fuel.	Increasing funding for alternate energy sources	2B	Further support in this area would not result in significant change in status of EHV. Impact of 3 Mile Island?
B. Federal Fleet Procurement	Initial Cost		x	Standards for federal procurement usage requirement: -12,000 miles/yr -life-span requirement: replacement after 6 yrs or 60,000 miles	Federal policies appear to favor vehicles meeting general standards at lowest initial cost. By ignoring life-cycle costs the procurement policies are biased against vehicles with high initial costs, but which offer savings through superior durability, lower maintenance requirements, or better fuel economy. Some biases against E.V.'s should be eliminated by	1) Eliminate/modify max. costs restrictions on automobile purchases by govt. 2) Have vehicle acquired on a life cycle cost basis 3) Direct GSA to purchase EHV's as a given percentage of its annual purchases .	1B	The EHV Act, low emission vehicle procurement programs are enactments on the books designed to foster use of EHV's. Except for post office use the federal agencies have been slow to incorporate EHV's in their fleets, even on a pilot basis. Strong executive direction may help in this instance. If government agencies refuse to purchase and operate EHV's in significant numbers, how can one convince private users to acquire them. Furthermore,

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					by Sec. 11 of the Electric and Hybrid Vehicle Act which directs federal agencies to study the possibility of E.V. procurement.			the acquisition of a sizeable government fleet would provide statistical operating experience which would be required by commercial institutions required to rate electric vehicles, While pilot government procurement would not be large enough to allow mass production of EHV's, it would allow development of operating data.
1. Low-Emission Vehicle Procurement Program	Emission System	x		Emission standards for federal procurement although authorized under the Clean Air Act has not been significantly implemented (i.e. $25,000 out of $20 million low emission vehicle demonstration project)	Bias could develop in favor of E.V.'s assuming these cars can satisfy individual agency needs.			See previous page comments on Federal Procurement Program Apply

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VI. AUTOMOTIVE INDUSTRY A. Industry Structure								
1. Economies of Scale	Flexibility of Performance, Interchangeability of Components		x	Requirements for operations: - full economies of scale reached at 250,000-400,000 vehicles per year -true market segmentation is limited to approx. 6 classes varying mostly by size	Bias against E.V.'s due to their limited range of performance capabilities, numerous specialized components and distinct design features	none	1A	For new technology to be implemented by the major mfgrs, predictable improvements in vehicle performance characteristics or reductions in mfg costs have to accrue. The U.S. industry is currently revamping its mfg base to meet AFER and is investing significant amounts of money to do so. Based on current performance characteristics, costs and market risk, mfgrs have no incentive to invest in equipment required to mfg EVs. If EV's placed under AFER, investment in technology becomes one of comparative risk rather than absolute risk. Rather than asking will EHV's succeed or fail, the question becomes what are the relative risks of investing in EHV technology as compared to another new technology that would be required in mfg to meet higher fuel economy standards.
2. Capital Requirements			x	Entrance requirements estimated to be -$2 billion	Bias against all new entrants and not against vehicle characteristics. However, high capital requirements create a bias within the existing "four," against the introduction of innovative new technology substantially altering vehicle characteristics.	none	1A	

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3. In-Place Infrastructure	Sales, Financing, Maintenance, and Resale Characteristics		x	Components of supporting infrastructure	It would appear that in-place infrastructure favors ICE's, but many infrastructure elements are consistent with or could easily be adapted to electric cars.	Support training programs for specialized technicians for EHV maintenance and repairs	2B	If Big 4 were to market EHV's the required sales and financing existing infrastructure would be used with EHVs. Maintenance facilities would have to be modified to accommodate special characteristics of EHVs. This would be done under sub-contract with electrical maintenance groups, or specialists. Non-dealer maintenance would require development of infrastructure and a need for trained personnel. Training grants would not be difficult to implement. Facility subsidies might be harder to accomplish.
						Support and/or subsidize installation of pilot EHV Maintenance facilities, either directly or indirectly with tax write offs	2C	
4. Demand Variations	Innovative Characteristics			Uncertainty of revenue due to demand variations	Demand fluctuations intensify the barriers to entry brought about by economies of scale and capital requirements			

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B. Industry Practice								
1. Research and Technological Innovation	Innovative Characteristics		x	Time-frame for introduction of innovative ideas	The introduction of major innovations is undertaken only after long studies and, if possible, in conjunction with the phasing out of fully depreciated facilities. The process is gradual due to the less than perfect competition among manufacturers and due to the risks involved, risks that are largely there because of automation. One factor that might reduce this time-frame is the expanding role of the foreign imports.	None	1A	
2. Pricing Practice and Profitability	Projected Profitability		x	Profitability of E.V.'s based on standards of target return pricing. (G.M. standards 20% return on capital with plants operating at 80% capacity)	The nature of the automobile industry (oligopoly) allows flexibility in determining productions volumes and price levels. Two consequences are target return pricing and higher than average profit expectations.	None	1A	

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VII Miscellaneous Factors								
A. OPEC								
1. Cartel-Set Oil prices	Fuel, Fuel Economy	x		Effects of high oil prices ($12-$13/barrel) on the transportation industry	Bias in favor of efficiency and non-oil consuming vehicles	None	0	
2. Potential	Fuel, Fuel Economy	x		Effects of scarcity of fuel on the transportation industry	Bias in favor of non-oil consuming cars	None	0	
B. Other Mineral Cartels	Raw Materials Need			Effects of pricing and availability of raw materials on the transportation industry	Potential supply restrictions should create no significant bias against particular vehicle characteristics. Availability of some materials and possible substitution of others will eliminate any potential bias.	None	0	
C. Foreign Energy Programs	Energy Efficiency			Effects of foreign competition on the transportation industry	Due to the greater dependency on imported oil, and therefore greater demand for alternate systems, foreign manufacturers could achieve significant economies of scale in E.V. production. Their products could then be introduced on the U.S.	None	0	Hypothetical situation at moment since EHV's are not mass produced anywhere in the world. If inexpensive EHV's were made overseas, possible action would be to allow these vehicles into the U.S. on a duty free basis as long as there was no significant manufacturer of EHV's in the U.S.

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					at lower prices spurring the U.S. manufacturers into competitive action.			If a domestic EHV manufacturing capability were developed, tariff could he set to standard automotive level.
D. Capital Availability and Markets	Innovative feature		x	Factors affecting the introduction of the vehicles	While no specific rules discriminating against E.V.'s exist, due to their absence from national underwriters rating list and the limited data on their insurance risk potential a possible bias against E.V.'s does exist			See Section IB8b p. 9 , insurance laws
E. Availability of Insurance	Value, Purpose, Crashworthiness, Theft, Potential, Damageability		x	Effect of specific vehicle characteristics on insurance availability	While no specific rules discriminating against E.V.'s exist, due to their absence from national underwriters rating list and the limited data on their insurance risk potential a possible bias against E.V.'s does exist			See Section IB8b p. 9, insurance laws
F. Financing	Resale Value		x	Availability of financing due to unmeasured vehicle potential	The bias is not specifically against E.V. reflecting the situation of most new durable products			See Section IB8b p.9, insurance laws

APPENDIX B

INSURABILITY AND LIABILITY

APPENDIX B

INSURABILITY AND LIABILITY

B-1 HISTORY OF AUTOMOBILE INSURANCE RATINGS

Automobile liability insurance dates from about 1898 when approximately 200 cars were manufactured in the United States (B-1). The initial policies were for third-party bodily injuries and were on a flat rate basis to a defined liability limit, applicable to personal use cars only. Property damage liability coverage was introduced in 1901. At the same time, insurance underwriters in England set premium rates varying with the horsepower of the car with one rate for under 12 horsepower and another rate for higher horsepower levels.

A more complete range of insurance options was also introduced in 1902. These included varying limits of liability for both bodily injury and property damage as well as accident and casualty insurance such as collision, and fire and theft coverage. The full range of coverages and the rates associated were set entirely on a judgmental basis, obviously with the hope that the collected premiums would exceed paid claims and expenses.

Until about 1915, there were only two classifications in use to determine the insurance rates. These were horsepower and type of motive power. The horsepower rates, described above, were further classified with a standard rate for cars in the 6 to 16 horsepower range, a preferred rate for cars under 6 horsepower (about a 20 percent premium reduction) and an increased rate at the higher horsepowers.

The type of motive power classifications was noted through the different rates charged for electric vehicles, gasoline powered or steam powered vehicles. In general, the electric vehicles seemed to have benefited from lower premiums than gasoline powered cars. Some viewed this preferential treatment of the electric vehicles as deriving from the perception that the electric cars were only capable of ordinary speeds, were used primarily for social purposes and were primarily driven by conservative operators. (B-2) The difference in rates

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(B-1) H. Jerome Zoffer, The History of Automobile Liability Insurance Rating, University of Pittsburgh Press, 1959.

(B-2) Robert C. Mead, The Making of Public Liability and Property Damage Rates, 1933 as cited in H. Jerome Zoffer, The History of Automobile Liability Insurance Rating, University of Pittsburgh Press, 1959.

can be noted from Table B-1 which describes the annual premiums for bodily injury and property damage liability in St. Louis and Chicago in 1915. It was about this time that the insurers were starting to use territorial classifications in their rate setting. The rates for electric cars were only provided at 40 horsepower in that insurance rates for electric cars were apparently never rated with horsepower.

In contrast to the favorable treatment of electric vehicles, higher rates, which also varied with horsepower, were set for steam powered vehicles. However, the standard policy, even at the higher rates, did not cover the hazard of boiler explosion, the protection for which had to be purchased on an extra rate basis.

TABLE B-1 AUTOMOBILE LIABILITY RATES - 1915
ST. LOUIS AND CHICAGO TERRITORY (B-3)

	Bodily Injury		Property Damage	
Horsepower	Gasoline	Electric	Gasoline	Electric
16	$22.50	$17.50	$ 5.63	$4.40
40	66.50	17.50	16.65	4.40
60	86.50	17.50	21.65	4.40

In those early days of automobile insurance, the premium rates were unrelated to actual experience or any statistical base of data. Some of the judgments used by the insurance companies to establish rates were primarily competitive, namely to secure additional policyholders by offering lower rates. The results were obvious. Some companies experienced greater losses than premiums received and either failed or left the market. The remaining companies realized the need to establish a firmer base for rate setting, and as with the horsepower, type of motive power and territorial classifications described above, started to acquire a data base, through a cooperative effort, which included use of the vehicle as a criterion. While the statistical references used to establish rates were to change significantly over the years (horsepower rating was dropped in 1926, list price was a rating reference in the early 1920's, etc.), insurance rates were statistically related to the actual incidence of accidents and losses incurred starting in 1923-1924.

(B-3) Robert C. Mead, The Making of Public Liability and Property Damage Rates, 1933 as cited in H. Jerome Zoffer, The History of Automobile Liability Insurance Rating, University of Pittsburgh Press, 1959.

Table B-2 summarizes motor vehicle factory sales of passenger cars in the United States in the first twenty years of the industry. The delay in moving to a statistical base for rates was not related to an insufficient number of vehicles but rather to the slow application of actuarial technology to the automobile industry. In 1916, Professor Robert Riegel of the University of Pennsylvania had suggested the need for a more extensive data base on which to develop rates more directly related to the nature of the risks being encountered. By 1930, sufficient data collection and analysis techniques were established to provide a reliable measure with approximately 5000 cars forming the base for rates within a geographical area.

TABLE B-2 MOTOR VEHICLE FACTORY SALES (B-4)

Year	Passenger Cars
1900	4,192
1902	9,000
1905	24,250
1910	181,000
1920	1,905,560

The ability to develop a statistical base for rate determination dates from about 1914 when various trade groups within the insurance industry started to compile statistics and to introduce the concept of an industry rate manual. While all companies did not subscribe to the rate manual (and many still do not), such industry wide ratings are still in use. The modern rate manual view of electric vehicles is described in Section 2.2.3.

In the 1930's, with the advent of technological improvements in body construction, braking systems and tire manufacture, the measured frequency and magnitude of loss initially decreased and rates dropped. Since the 1940's, the changing role of the automobile in our society, the extensive development of the highway and roads system, the impact of safety criteria in automotive design, and regulatory criteria, etc. have resulted in a complex array of state requirements for insurance and numerous rating criteria which attempt to take account of driver characteristics, use of the automobile, costs of repaid, medical costs, etc. While substantial data are available to the rate making process, the current trends are seriously questioning the structure of modern

(B-4) Motor Vehicle Manufacturers Association Facts and Figures '78.

automobile insurance concepts and rates.

B-2 EXAMPLES OF DATA ON REPAIRABILITY, DAMAGEABILITY AND CLAIM FREQUENCY

The data shown in Table B-3 is one factor arguing for individual automobile repairability being reflected in the rates for property damage insurance.

TABLE B-3 REPAIR COSTS - CHEVROLET IMPALA (B-5)

	1973		1979	
	Parts	Labor	Parts	Labor
Front Bumper	$241.80	$ 39.57	$ 495.68	$ 49.74
Grille	77.78	29.92	202.95	32.19
Hood	134.94	23.16	252.10	42.43
Front Fender	179.90	59.83	226.75	68.76
Totals	$634.42	$152.48	$1,177.48	$193.12

1973 Chevrolet Impala damaged in February 1974 with labor rate at $9.65 per hour.

1979 Chevrolet Impala damaged in January 1979 with labor rate at $14.63 per hour.

If all factors regarding the incidence of property damage accidents incurred by Chevrolet Impalas were constant over the 1973 to 1979 period, the higher costs to repaid should be expected to be reflected in the rates.

However, in addition to the increased costs to repair over time, test data on selected vehicle damageability are also being considered. Table B-4 shows the estimated cost to repair 1979 model subcompacts and compacts under different impact conditions. Aside from the differences between the subcompacts and the compacts, the large variations in estimated repair costs within each class highlight the issue of damageability.

Risk assessment is not only based on the level of damage that might be sustained but also is an attempt to predict future events, one year at a time, on the basis of past events. Typical of the data being collected by the industry is the summary for collision coverage for 1978 and 1979 models shown in Table B-5. Such information is collected and evaluated for each model design, manufacturer, year of manufacturer, type of insurance coverage, etc. It is

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(B-5) Insurance Facts 1979, Insurance Information Institute, New York.

TABLE B-4 LOW-SPEED CRASH TEST RESULTS

1979 Model Cars
Estimated Cost to Repair (B-6)

	5 MPH Front to Angle Barrier	5 MPH Rear into Pole	10 MPH Front to Angle Barrier	10 MPH Front into Rear: Front Damage	10 MPH Front into Rear: Rear Damage
Subcompacts					
Plymouth Horizon	$159	$114	$ 547	$ 37	$ 16
AMC Spirit	248	140	796	12	0
Ford Mustang III	14	259	945	46	6
Volkswagen Rabbit	172	119	1036	39	96
Chevrolet Chevette	272	167	874	46	155
Average	173	160	840	36	55
Compacts					
AMC Concord	273	144	750	18	48
Plymouth Volare	271	179	795	131	142
Chevrolet Malibu	366	168	990	284	191
Ford Fairmount	361	220	914	722	203
Average	318	178	862	289	146

(B-6) Insurance Institute for Highway Safety as cited in Insurance Facts 1979, Insurance Information Institute, New York.

through an evaluation of such experience that the insurance underwriters assess which risks they are willing to insure and at what rates, subject to the rate making provisions within each state.

B-3 SURVEY BY COMMONWEALTH RESEARCH GROUP, INC. (CRG)

A survey of insurance companies was performed by CRG, as per the letter shown as ATTACHMENT B-1. The responses to this letter are summarized in Appendix B-4.

B-4 POSTAL SERVICE ACCIDENT EXPERIENCE

Assistant Postmaster General Edward E. Horgan, Jr. testified to the Senate Committee on Appropriations, Transportation Subcommittee on June 4, 1979 on the safety experience of their electric vehicle fleet. By letter of June 13, 1979

TABLE B-5 LOSS EXPERIENCE SUMMARY BY VEHICLE SIZE AND MODEL YEAR - COLLISION COVERAGE (B-7)

	Claim Frequency Per 100 Insured Vehicle Years			Average Loss Payment Per Claim ($)			Average Loss Payment Per Insured Vehicle Year ($)		
Models	1978		1979	1978		1979	1978		1979
Time Period	9/77-2/78	9/78-2/79	9/78-2/79	9/77-2/78	9/78-2/79	9/78-2/79	9/77/2/78	9/78-2/79	9/78-2/79
SubCompact (101" Wheelbase)	11.1	12.6	13.8	889	996	1129	99	126	156
Compact (101 - 111" Wheelbase)	10.3	11.5	11.6	840	931	946	87	107	110
Intermediate (111 - 120" Wheelbase)	9.4	10.7	9.6	828	898	975	78	96	94
Full Size (120" Wheelbase)	10.6	11.5	11.1	939	960	1131	100	110	126
All Cars			11.7			1029			120

(B-7) Highway Loss Data Institute as reported in Insurace Facts 1979, Insurance Information Institute, New York.

COMMONWEALTH RESEARCH GROUP, INC.
230 BEACON STREET
BOSTON, MASSACHUSETTS 02116
(617) 536-3146

ATTACHMENT B-1

Dear

Commonwealth Research Group, Inc. is an economic consulting firm presently engaged in analyzing factors affecting the commercialization of electric and hybrid vehicles. We are currently working with "Argos" Associates under contract to the U.S. Department of Transportation to update a study of the insurability of these vehicles, which we conducted two years ago.

In conducting a follow-up to our initial study, we are interested in finding out whether the insurability of electric and hybrid vehicles has changed in the last two years, and if so, in what way. We would greatly appreciate your help in answering the following questions:

(1) What is your company's current level of experience with the insurance of electric and hybrid vehicles?

(2) Does your company have any restrictions or biases in its rates with respect to electric and hybrid vehicles?

(3) Has your policy on electric and hybrid vehicles changed in the last two years?

(4) Have the results of electric vehicle road tests during the last two years altered your policy, and if so, in what way?

ATTACHMENT B-1 (CONTINUED)

(5) What kinds of data on electric and hybrid vehicles do you still need to obtain?

(6) What problems do you now face in insuring electric and hybrid vehicles?

(7) Do you foresee any future problems in the insurance of electric and hybrid vehicles?

Thank you for any information that you might be able to provide us. Naturally, any such information will be treated in confidence should you desire.

Yours sincerely,

ETK:bdw

C R G

B-4 SUMMARY OF INSURANCE COMPANY RESPONSES

Question 1: What is your company's current level of experience with the insurance of electric and hybrid vehicles?

Response: All 29 responding companies reported extremely limited or no insurance experience.

Question 2: Does your company have any restrictions or biases in its rates with respect to electric and hybrid vehicles?

Response: Of the 29 responding companies, only one declared outright that it would not insure electric or hybrid vehicles. Fourteen companies offered to do so with no biases or restrictions on rates. Seven followed the guidelines of the Insurance Services Office*, which recommends a 25% discount from applicable private passenger base premiums, with no restrictions. Two firms offered a 25% reduction for coverage of Bodily Injury Liability and Property Damage Liability, and one offered an 80% rate for electric vehicles less than 1,500 pounds and 45 mph maximum speed. Other companies mentioned insufficient credible information with which to formulate a general underwriting policy for electric vehicles, but expressed a willingness to insure such vehicles on a case-by-case basis.

Question 3: Has your policy on electric and hybrid vehicles changed in the past two years?

Response: None of the companies reported any changes over the past two years, with the exception of those firms that adopted the Insurance Service Office's 25% discount instituted in November of 1978.

Question 4: Have the results of electric vehicle road tests during the last two years altered your policy, and if so, in what way?

Response: Twenty-six respondents reported no alterations. One said road test results had gotten them more interested in electric vehicles, while another reported a negative influence, since some vehicles have not met the National Highway Traffic Safety Administrator's safety standards. Another mentioned increased interest due to results showing improved safety equipment.

Question 5: What kinds of data on electric and hybrid vehicles do you still need to obtain?

Response: Respondents expressed the need for a wide variety of information. Most frequently mentioned was the need for a large data base from in-use vehicles with which to make actuarial computations. In particular, they were interested in statistics on crashworthiness and damageability, as well as frequency of repair. The other major concerns were for information on the location and quality of repair facilities, and on repair costs. Some respondents also expressed interest in more information on vehicle characteristics, such as speed, acceleration, range, weight ratio, braking, padding and passenger protection, and use of vehicles. However, the main concern expressed throughout the responses to all of the questions was for a larger data base on in-use performance to facilitate policy underwriting.

Question 6: What problems do you now face in insuring electric and hybrid vehicles?

Response: Eight respondents said they had no problems. Thirteen mentioned their lack of experience as a problem, and four mentioned problems with insufficient data. One respondent mentioned that the performance capabilities of electric vehicles are not up to highway standards, and two noted that the variety of different units on the market makes safety determination difficult.

Question 7: Do you foresee any future problems in the insurance of electric and hybrid vehicles?

Response: Fourteen respondents foresaw no problems. Other respondents mentioned a variety of problems, but these were not generally seen as insurmountable. Most frequently mentioned were: limits to speed and acceleration; the small size of the vehicles; potentially high repair costs; and problems getting replacement parts. Limits to range, lack of historical data, battery explosion exposure, and deficient vehicles produced by opportunistic firms were also mentioned as possible problems.

*Note: The Insurance Services Office is a New York based firm which supplies information and suggested guidelines to insurance companies. As noted, they recommend a 25% discount from applicable private passenger base premiums for electric vehicles. Roughly 250 insurance companies per state subscribe to their service on a filing authorization basis. These firms are free to ignore the recommendations as they wish, but many do follow the guidelines. I.S.O. recommends the discount on the basis of the limited mileage and speed characteristics of present-day electric vehicles. As of June, 1980, they will have in use a program to segregate data on electric vehicles from claims reports, and will begin to establish a data base. Possible future problems they mentioned include the cost of repairs, damageability, and the variety of models available.

to Senator McClure, the following statistics were presented: (B-8)

" U.S. POSTAL SERVICE

Vehicle Accidents: 1/4 Ton Electric Vehicles vs. 1/4 Ton Conventional Vehicles

Background

In FY 78 there were nine (9) vehicle accidents involving the 1/4 ton electric vehicles. None of these involved a pedestrian or occurred while in a backing maneuver. Eight (8) of the accidents occurred on a postal route and one (1) occurred while the vehicle was being shuttled.

Rate Comparison
Accidents Per 100 Vehicles

In FY 78, with a fleet of 380 electric vehicles, the accident rate per 100 electric vehicles was 2.4. In FY 77*, with a fleet of 77,970 conventional vehicles of the same configuration, there were 4,105 vehicle accidents involving the 1/4 ton conventional vehicles. The vehicle accident rate per 100 conventional vehicles was 5.3.

Accidents Per 1,000,000 Miles Driven

1/4 Ton Electric Vehicles, FY 78:	6.3
1/4 Ton Conventional Vehicles, FY 77*"	10.5

*Statistics for conventional vehicles not yet available for 1978"

B-5 PRODUCT LIABILITY LAW

There are three legal concepts under which product liability may be based:

(1) warranty

(2) negligence

(3) strict liability

The warranty concept is not based on the fault of the seller or on any breach of a duty of care that the seller may owe to the user. It is a contractual concept under which a liability arises when physical injury results from a product's failure to meet any expressed or implied warranties made by the seller. An express warranty results from the seller making a definitive statement about the product--"EHV when fully charged has 100 miles range."--which statement forms the basis of the bargain between the seller and purchaser. The word

(B-8) Senate Hearings Before the Committee on Appropriations, Role of Electric Vehicles in U.S. Transportation, 96th Congress, First Session, June 4, 1979, page 350.

"warranty" need not be used for an express warranty to be created and it may result from a general description of the product, by the showing of a sample or by advertising brochures. The critical aspect of an express warranty is that the consumer relied upon the warranty.

The law also imposes an implied warranty in sales from merchants to consumers, namely the implied warranty of merchantability. This warranty holds the product to be fit for the ordinary purposes for which the product is intended. In general, fitness for ordinary purposes is meant to include reasonable safety or fitness for normal use of the product--would the EHV be expected to be as fit as an ICEV for normal driving use? A special type of implied warranty, the implied warranty of fitness for a particular purpose, may be created when the consumer advises the seller of the particular purpose for which the product will be used and, relying upon the expertise of the seller, uses the product for that purpose.

In general, the sellers of products cannot effectively limit their warranty liability through the use of disclaimers where such disclaimers are considered contrary to public policy. Typically, this restriction applies to all attempts to limit warranty liability for personal injuries in consumer products.

Negligence is a tort concept based on the fault of the seller. The seller is liable in negligence when a physical injury results from the seller's failure to meet its duty of care. The duty of care is that obligation which the seller has to exercise of all reasonable care regarding the forseeable use of the product. The breach of that duty may result from those negligent acts (or failures to act) which include improper design of the product, improper assembly or manufacture of the product, failure to provide adequate warnings, failure to adequately test or inspect for defects, improper instructions, etc. Some of the acts of negligence may apply to only one unit of the product--improper assembly. Alternatively, design defects such as poor material choices or lack of safety devices may result in a more extensive liability affecting all of the product units manufactured.

The seller is also obligated to warn about any dangerous aspects of the product in that the seller is expected to be more knowledgeable than the user. In addition, the question of the need and adequacy of any warning regarding use of the product must be balanced against the nature of the risk and extent of harm from such use.

A seller's obligation to provide warnings should not be confused with its obligation to provide adequate instructions regarding the use of the product. In addition, the adequacy of instructions would also be evaluated in the context of whether the instructions reasonably educated the users as to the safe and proper use of the product.

In all of the circumstances under which the negligence theory of liability prevails, the negligent act (or non-act) must directly relate to the physical harm incurred.

The most important modern concept of product liability is that of strict liability. This tort concept is neither based on fault nor is it an absolute liability depending merely on the existence of damage. The concept of strict liability holds the seller responsible for that physical damage which results from a product defect. The injured party must show that the product was defective at the time it left the control of the seller and that such defect was the cause of the damage. This concept of strict liability was firmly established as a modern doctrine in a 1963 California case (B-9) which stated:

> "...A manufacturer is strictly liable in tort when an article he places on the market, knowing that it is to be used without inspection for defects, proves to have a defect that causes injury to a human being...and a retailer selling such an article is subject to the same rule."
>
> "...the purpose of such liability is to insure that the costs of injuries resulting from defective products are borne by the manufacturers that put such products on the market rather than by the injured persons who are powerless to protect themselves."

In 1965, the American Law Institute added Section 402A to the Restatement (Second) of Torts. This compilation of the major concepts of tort law, while not binding on the courts, has a major influence on both the legislatures and the courts. Section 402A, which has now been followed in almost all the states, though not specifically in the same form, describes strict liability in tort as follows:

> "Special Liability of Product for Physical Harm to User or Consumer
>
> (1) Who sells any product in a defective condition unreasonably dangerous to the user or consumer or to his property is subject to liability for physical harm thereby caused to the ultimate user or consumer, or to his property, if
>
> (a) the seller is engaged in the business of selling such a product, and

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(B-9) Greenman v. Yuba Power Products, Inc. 377 Pacific 2d 897 (1963).

(b) it is expected to and does reach the user or consumer without substantial change in the condition in which it is sold.

(2) The rule stated in Subsection (1) applies though

(a) the seller has exercised all possible care in the preparation and sale of his product, and

(b) the user or consumer has not bought the product from or entered into any contractual relation with the seller." (B-10)

In commentary to this Section, the rationale is noted:

"On whatever theory, the justification for the strict liability has been said to be that the seller, by marketing his product for use and consumption, has undertaken and assumed a special responsibility toward any member of the consuming public who may be injured by it; that the public has a right to and does expect, in the case of products which it needs and for which it is forced to rely upon the seller, that reputable sellers will stand behind their goods; that public policy demands that the burden of accidental injuries caused by products intended for consumption be placed upon those who market them, and be treated as a cost of production against which liability insurance can be obtained; and that the consumer of such products is entitled to the maximum of protection at the hands of someone, and the proper persons to afford it are those who market the products." (B-11)

It is important to note that the views of Section 402A have been extended by some courts to include lessors of products as responsible parties and bystanders, in addition to users, as a protected group.

While warranty and negligence are still viable concepts, the thrust of product liability has shifted the area of consumer protection from one in which the seller's conduct was at fault (negligence) to the seller's product being at fault (the "defect"). The important questions that then arise are those necessary to understand the nature of a defect.

Defects have been described as being basically of three types: manufacturing flaws, inadequacies of warning and design defects. (B-12) While manufacturing flaws and inadequacies of warnings are often described defects in strict liability litigation, there are characteristics of design defects which

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(B-10) Restatement (Second) of Torts Section 402A (1965).

(B-11) Restatement (Second) of Torts Section 402A, Comment C (1965).

(B-12) J. J. Phillips, The Standard for Determining Defectiveness in Product Liability, 46 University of Cincinnati Law Review 101 (1977).

are uniquely applicable to the EHV and its current stage of development and which are described in Section 2.3.6.

Generally, the feasibility of making a safer product is at issue in determining the existence of a design defect. (B-13) However, the question of feasibility may be either one of technology or of economics. The fact that it is not technologically feasible to remove a design defect may lead to the concept of the unavoidably unsafe product which excuses liability.

> "There are some products which, in the present state of human knowledge, are quite incapable of being made safe for their intended and ordinary use. These are especially common in the field of drugs....Such a product, properly prepared, and accompanied by proper directions and warning, is not defective, nor is it unreasonably dangerous...." (B-14)

Determining whether it was feasible to design a safer product necessarily requires a balancing of the utility of the product against the technological feasibility of a better design and the magnitude of the risk in selling the product in its present state of development. However, the question of what is technically feasible as the basis of determining the existence of a defect is not solely related to the state-of-the-art at the time of manufacture or of sale. While the state-of-the-art at the time of manufacture or sale was usually an acceptable defense under the negligence concept, it appears to be disappearing as a viable defense to strict liability actions. (B-15)

Similarly, it may not be economically feasible to remove a design defect. Here the burden on the seller is similar as in the defense of technical non-feasibility. The seller must show that the utility of the product without the added cost of an improved design outweighs the potential risks of harm. This burden on the manufacturer was further emphaszied in a recent California case (B-16) in which the court indicated that a manufacturer must show that the usefulness of a product involved in an accident outweighs the risks inherent in

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(B-13) J. J. Phillips, The Standard for Determining Defectiveness in Product Liability, 46 University of Cincinnati Law Review 101 (1977).

(B-14) Restatement (Second) of Torts, Section 402A, Comment K (1965).

(B-15) Karazik, State of the Art or Science: Is It a Defense to Products Liability?, 60 Illinois Bar Journal 348 (1972) as cited in J. J. Phillips, The Standard for Determining Defectiveness in Product Liability, 46 University of Cincinnati Law Review 101 (1977).

(B-16) Barber v. Lull Engineering Co., 573 Pacific 2d 443 (1978).

its design. The court stated the following two part test to define a product defect:

"[1]n design defect cases a court may properly instruct a jury that a product is defective in design if (1) the plaintiff proves that the product failed to perform as safely as an ordinary consumer would expect when used in an intended or reasonably forseeable manner, or (2) the plaintiff proves that the product's design proximately caused injury and the defendant fails to prove, in light of all the relevant factors, on balance the benefits of the challenged design outweigh the risk of danger inherent in such design."

Among the criteria to be considered in determining the existence of a product defect, in addition to that of utility, is the availability of other and safer products to meet the same needs. (B-17) The relative status of the performance and safety design characteristics of present EHV's and the ICEV's might be considered in this regard.

With the active participation of the federal government in the promulgation of motor vehicle safety standards and its current role in fostering the development of the EHV, it is especially important to note that the courts have traditionally viewed safety standards as minimal limits for product acceptability. As such, compliance with a standard does not necessarily mean that a product does not have a design defect. While the case law is slowly developing in this area (B-18), others have noted that compliance with safety standards under the National Traffic and Motor Vehicle Safety Act of 1966 or with agency standards under the Consumer Products Safety Act does not bar an action against the seller. (B-19)

B-17) J. Wade, Strict Liability of Manufacturers, 19 Southwestern Law Journal 5 (1965) as cited in A. Weinstein, et al., Products Liability and the Reasonably Safe Product: A Guide for Management, Design and Marketing, John Wiley, New York (1978).

(B-18) Berkebile v. Brantly Helicopter Corporation, 337 Atlantic 2d 893 (1975), Buccery v. General Motors Corporation 132 California Reports 605 (1976).

(B-19) J. Little, Consumer Satisfaction with the Extent of Government Induced Vehicle Safety Design as Indicated by Judges and Jurors in Tort Litigation Decisions Arising out of Alleged Defective Design: Prognosis for the 1980's, Fifth International Congress on Automotive Safety Proceedings, U.S. Department of Transportation (1977), A. Weinstein, et al., Products Liability and the Reasonably Safe Product: A Guide for Management, Design and Marketing, John Wiley, New York (1978).

B-6 PRODUCT LIABILITY INSURANCE RATES IN THE AUTOMOTIVE SECTOR

The Interagency Task Force Study (B-20) provided an estimate of the product liability insurance rate, expressed as a percentage of sales, from information available regarding rates for the basic coverage limits, and adjustment to increase the liability limit covered. The estimates for those categories of automobile components that might relate to the electric vehicle are shown in Tables B-7 to B-9. The estimates presented in those tables were based on 43 companies who manufactured automobile components and tires and which had the sales history in 1975 given in Table B-6.

TABLE B-6 SALES OF COMPANIES IN AUTOMOTIVE SECTOR SURVEYED

1975 Sales Dollars	Number of Companies
Not reported	5
Less than 1 million	12
1 million to 10 million	7
10 million to 50 million	8
More than 100 million	11
Total:	43

TABLE B-7 BASIC RATES FOR PRODUCT LIABILITY INSURANCE (B-21)

	Combined BI and PD Rate per $1000 Sales
Auto accessories	$1.16
Auto bodies, excluding tires	4.30
Auto, bus and truck brake linings	5.00
Auto, bus and truck parts	7.25
Motor vehicles, personal type	5.50 - 16.50

Basic BI (bodily injury coverage) has aggregate limit of $50,000 and basic PD (property damage coverage) has aggregate limit of $25,000. Per occurrence limits are $25,000 and $5,000, respectively.

(B-20) Interagency Task Force on Product Liability PB-262-515, Briefing Report, (January 1977).

(B-21) Insurance Services Office as reported in Table V-4 in Interagency Task Force on Product Liability: Final Report, U.S. Department of Commerce PB 273-220 (November 1977).

TABLE B-8 PREMIUMS FOR A COMBINED LIMIT OF LIABILITY OF $500,000 FOR BOTH BODILY INJURY AND PROPERTY DAMAGE (B-22)

	Combined BI and PD Rate Per $1000 Sales
Auto, bus and truck accessories, not operating parts	$ 4.20
Auto Bodies	9.20 (a)
Auto, bus and truck brake linings	12.40 (a)
Batteries - storage	2.30
Motor vehicles, personal type	14.40 (a)

Calculations reflect basic limit rates and increased limits factor up to a limit of liability of $500,000 for both bodily injury and property damage. Rates do not reflect application of experience or the influence of deductible programs. Basic limit manual rates available in 1976 were applied where applicable and (a) rates were result of modifications to reflect actual pricing practices used in sample companies.

(B-22) Exhibit C-2 in Interagency Task Force on Product Liability Final Report of the Insurance Study-Volume I, ITFPL-77/03, U.S. Department of Commerce PB 263-600 (1977).

TABLE B-9 PREMIUMS FOR COVERAGE OF $250,000 BI, $50,000 PD PER OCCURRENCE (B-23)

	Combined BI and PD Rate per $1000 Sales
Auto bodies, excluding trailers	$12.44 (a)
Auto, bus and truck brake linings	14.45 (a)
Auto, bus and truck parts	20.90 (a)
Motor vehicles, personal type	14.40 - 40.20 (a)
Automotive manufacturing	11.10 - 28.10 (a)

These rates reflect basic limit rates and increased limits factor. They do not reflect application of experience, schedule modification or the influence of deductible programs. Basic limit manual rates available in 1976 were applied where applicable and (a) rates were result of modifications to reflect actual pricing practices used in sample companies.

(B-23) Table V-6 in Interagency Task Force on Product Liability: Final Report, U.S. Department of Commerce PB 273-220 (November 1977).

The Task Force studies indicated differing rates in regard to the size category of the company. The relative impact of sales on the product liability rates for manufacturers of automotive components can be inferred from Table B-10.

TABLE B-10 AVERAGE PREMIUMS PER $1000 IN SALES FOR COMPREHENSIVE GENERAL LIABILITY/COVERAGE BY SIZE CATEGORY OF COMPANY (B-24)

	< 2.5 Million Sales	2.5 to 100 Million Sales	> 100 Million Sales	All Companies
Comprehensive General Liability Coverage for Automotive Components	$6.50	$2.60	$1.26	$2.94
Comprehensive General Liability Coverage For All Surveyed Products	7.42	3.88	1.24	3.59
Estimated Product Liability Coverage For All Surveyed Products	5.32	3.23	1.09	2.81

(B-24) Tables V-10 and V-11 in Interagency Task Force on Product Liability: Final Report, U.S. Department of Commerce PB 273-220 (November 1977) incorporating the results of the Product Liability Industry Telephone Survey conducted by Gordon Associates, Inc. in December 1976.

B-7 CLOSED CLAIMS SURVEY (B-25)

The Insurance Services Office (ISO) study of deed claims extended beyond automotive products. Table B-10 shows overall claims included in the study categorized by form of damage.

TABLE B-11 OVERALL PRODUCT LIABILITY CLOSED CLAIMS

	% of Number of Paid Claims	% of Paid Claim Dollars	Average Payment Per Claim
Bodily Injury Only	61	83	$13,911
Property Damage Only	37	13	3,798
Combined Damage	2	4	---

(B-25) Insurance Services Office (ISO) Product Liability Closed Claim Survey: A Technical Analysis of Survey Results, Insurance Services Office (1977).

Table B-12 presents the survey results for the closed claims related to automobile parts and products, expressed as a percentage of the number and dollars paid claims and in relation to other product categories. Two characteristics of the automobile products are evident. They were the leading product group in regard to the percentage of all paid claim dollars and one of the most frequent sources of the number of paid claims for both bodily injury and property damage. While the average payment for automotive parts and products claims were almost five times the overall average, such claims did not represent the highest average payment amounts. The range of average payments for product categories with at least fifty paid claimants in the sample is shown in Table B-13.

TABLE B-12 SEVERITY OF AUTOMOBILE PARTS AND PRODUCTS CLAIMS

Category	% of Number of Paid Claims	% of Paid Claim Dollars	Average Payment	Rank	
				Number	Dollars
Bodily Injury	3.2	7.8	$64,091	7th	1st
Property Damage	5.7	10.8	13,134	2nd	1st

Rank refers to the frequency of the number of paid claims and the paid claim dollars for the automobile parts and products claims relative to other products. For example, there were six other product categories which had a higher percentage of the total number of claims for bodily injury than automobile parts and products. The number of product categories in each ranking were:

Damage	Group	Product Categories
Bodily Injury	Number	25
Bodily Injury	Dollars	27
Property Damage	Number	37
Property Damage	Dollars	28

TABLE B-13 RANGE OF AVERAGE PAYMENTS PER PRODUCT CATEGORY WITH AT LEAST FIFTY CLAIMANTS AND RANK OF AVERAGE PAYMENT FOR AUTOMOBILE PARTS AND PRODUCTS CATEGORY

	Number of Categories With 50 or More Paid Claims	Average Payment $		Automobile Products	
		Low	High	No. of Paid Claims	Rank of Average Payment
Bodily Injury	25	366	171,173	264	6th
Property Damage	25	126	34,755	292	5th

APPENDIX C

SUPPORT FACILITIES FOR ELECTRIC VEHICLE RECHARGING

APPENDIX C

Support Facilities for Electrical Vehicle Recharging

C-1 INTRODUCTION

In considering recharging of electric vehicles batteries at the user level, one has to distinguish between two fundamentally different modes of operation. The first mode entails the periodic recharging of EV batteries at the user's home base of operations, and provides the EV with the energy required to satisfy most routine driving needs. The second mode entails the recharging of EV batteries at locations other than at the home base of operations of the EV operator, to provide the EV operator with range extension, thereby increasing the mobility of EV's. In this Appendix, the requirements for home base recharging and the associated institutional characteristics will be considered.

C-2 DEFINITIONS AND REQUIREMENTS EV HOME BASE RECHARGING

The requirements for recharging of EV batteries at the EV operator's base of operation are:

1. Availability of off-street parking.
2. Access to electrical service.
3. Unused electric service capacity of at least 50 amperes, 230 volt during the EV battery charging cycle.
4. A non-hazardous area where recharging can be performed safely.

The first two requirements are self explanatory. It is necessary for the EV operator to have direct access to both land and electric power to perform the recharging operation. This question of access divides potential EV operators into two major groups:

a) owners

b) lessees (tenants)

of property on which it is proposed to recharge the electric vehicle.

EV operators who are owners of property can be further classified as either business and institutions, or individuals. The distinction is made because the capacity of the electric service required by an enterprise, be it commercial or non-profit in nature, is usually much larger than that required by an individual home owner.

Given access to parking and electricity, further consideration is the quality of the available electrical service and the space provided for the recharging operation. The electrical service has to be large enough to accommodate the peak power drawn by the EV during charging. Based on the National

Electrical Code, the branch service to which the EV charger is connected has to have a minimum rating of 230 volt and 50 amperes (or 11.5 kW). Service entry lines, panels and fuses furthermore have to be large enough to accommodate this load, and all other concurrent electrical demands of the facility where the EV (or EV's) is (are) being recharged. As far as the quality of the area where EV recharging would be performed, the major issue is safety, and the major concern is providing adequate ventilation to insure against the accumulation of explosive mixtures of hydrogen and air that can be formed during the charging cycle.

Issues of interest to the present study are the current and future availability of these facilities, and the costs of providing such facilities to the utilities and to various groups of potential EV owners. The current and future availability of EV recharging facilities for various categories of EV operators will be discussed further below.

C-3 IMPACT OF ELECTRIC VEHICLE RECHARGING ON OPERATIONS OF ELECTRIC UTILITIES

By restricting electric vehicle recharging to offpeak hours, most electric utilities will be capable of supporting a significant fleet of electric vehicles with their existing generating capacity, as discussed in Chapter 3. Required system or equipment modifications will occur principally at the local distribution points where electricity is transferred from the utility's power lines to the electric service of the customer. The utility will have to modify the existing entrance service in order to restrict or encourage the recharging of EV's to off-peak hours. Any physical modifications in the electric service would also have to be accompanied by appropriate rate structures for the electricity sold that will make it economically attractive for the customer to preferentially use off-peak power for EV recharging. The principal distribution options available to the utility area:

a) Provide a separate service for EV recharging that can operate only during predetermined off-peak hours, or that can be interrupted at the discretion of the utility,

b) Utilize the existing service now provided a customer, replacing the existing single readout meter with a dual reading meter indicating time of day use, or adding a sub-meter to the EV branch circuit.

C-3-1 Installation of Separate Service

The cost to the utility of providing a separate service will consist of three major cost elements:

a) cost of installing the wiring between the utility pole and the head of service

b) cost of installing the electric meters to measure electricity consumption and demand (for commercial customers only)

c) cost of installing or providing switching equipment that controls the use of electricity

a) Residential Service for One Electric Vehicle

The cost of installing the wiring between the utility pole and the head of service will depend on the current and voltage of the electrical service to be provided, the distance between the pole and the service connection, and whether the service connection is under ground or overhead. It is much less expensive to provide additional overhead service than additional underground service. The cost of providing a 500 foot overhead connection for a 1 phase, 220 volt, 100 ampere 3 wire service is estimated to be as follows:

Materials	(600 volt, copper conductor, #4 AWG, type THWN; supports and connectors)	$50
Labor	1 Electrician - 1 man hour @ $20/hour	$20
	Total	$70

Providing an underground service will be much more expensive. If the existing electrical conduit is not completely filled, it would be possible to place the wiring for the new service in the conduit. Pulling a cable in this manner is a fairly slow process in comparison to stringing it between two elevated points, especially if the conduit is not straight. It is not unreasonable to assume that passing wiring through a 50 foot long conduit may occupy a crew of two electricians for a full day. In this case, installation labor costs would be $320 instead of $20, and total installation costs would be $370. If there is no available space in existing conduits, then it would be necessary to install a new conduit which becomes very expensive because this will require excavation work. The existing street or sidewalk may have to be demolished, a trench would have to be dug, an entry for the new conduit would have to be made in the building, the conduit would have to be installed, the building masonry would have to be repaired, earth would be backfilled and compacted over the conduit, and concrete or cement would be laid to repave the street or sidewalk. All this work, which would be in addition to the threading of the wiring through the conduit, could add thousands of dollars to the cost of providing a new service.

The major U.S. manufacturers of electric utility meters are Duncan Electric Company, Inc., General Electric Company, Sangamo Electric Company and Westinghouse Electric Corporation. The characteristics and costs of standard electric utility meters, as well as new lines of programmable and multiple-rate meters, being marketed by these manufacturers were reviewed in a recent study performed by Arthur D. Little Inc., and prepared for the Electric Utility Rate Design Study (C-1). According to this study, a standard three wire 240 volt, class 100 watt-hour meter that would be suitable for residential use, would have cost a utility $22 in September 1978. Cost of installation was estimated to be an additional $3. Total installed cost would thus be $25.

Control of electrical service on a time of day basis would require installation of a time switch to activate the circuit. The cost of a time switch (such as Sangamo Model WHR 21A), with backup capability would be $83, with installation costs ranging from $8 to $16, depending on location. Control of electrical service on an interruptible basis would require the installation of a radio controlled or ripple controlled switch that would be activated by a signal from utility control operations. Costs of this equipment, which is still in the developmental stage, were not obtained. It is anticipated that such remotely controlled switching would be more expensive than a time switch.

The costs of the above alternates are summarized in Table C-1.

b) Industrial/Commercial Service for Electric Vehicle Fleets

The capital cost to the utility of providing electric service to an industrial/commercial customer of electricity is higher than its cost for providing service to a residential customer. This is principally due to the higher electrical power consumption of industrial/commercial users. Furthermore, the cost of electricity for these customers is a function of both total energy consumption and peak demand, which requires that two separate types of meters be installed.

In the following calculation, it will be assumed that for the maximum industrial/commercial customer will require a separate electric service to support the recharging of a fleet of ten electric vehicles. The utility will provide the necessary transformers, 100 foot service connections, meters and switches. These costs are summarized in Table C-2 for an overhead service drop.

If a new underground service would have to be provided, it is estimated that the total costs would increase by $1000, if existing conduits be used, and significantly more if new conduits had to be installed. These costs are also presented in Table C-1.

(C-1) "Load Controls and Equipment for Using Off-Peak Energy," Prepared for Electric Utility Rate Design Study by Arthur D. Little, Inc., Cambridge, MA 02142, May 15, 1979.

TABLE C-1 CAPITAL COST TO THE ELECTRIC COMPANY OF PROVIDING SEPARATELY METERED ELECTRIC SERVICE FOR E.V. RECHARGING

Separate Service with Restricted Time of Day Use	Estimated Installed Cost* per EV$ Residential Customer	10 EV Fleet Commercial Customer
Overhead service	$190	$400
Underground service (using) electric conduits)	$500	$500
Underground	>$5000	>$5000
Using Existing Service Drop to Customer		
Metered Branch Circuit with Time Switch	$120	$30
Installing Dual Register Time of Day Meters	$150	$50

*1978 Basis

TABLE C-2 ESTIMATED COST TO THE UTILITY OF PROVIDING A SEPARATE OVERHEAD SERVICE TO AN INDUSTRIAL/CUSTOMER FOR THE RECHARGING OF A 10 UNIT ELECTRIC VEHICLE FLEET *

	MATERIALS	LABOR	TOTAL
Transformer (5 kv or 15 kv primary 277/480 secondary) oil Filled, 150 KVA Rating	$1800	$460	$2260
Wiring (100 ft. connection, Type 500 MCM, 3 conductor)	900	120	$1020
Misc. Connectors			$ 20
Sub-total			$3300
Watt Hour Meter	180	20	200
Demand Meter	180-480	20	200-$400
Time Switch	83	17	100
Total			$3800-$4000
Estimated per Vehicle			~ $400

* 1978 basis

C-3-2 Utilization of Existing Service

The utility company could also provide the electricity required for EV recharging on a customer's existing service, and still provide the incentive or control for off-peak charging by installing either:

a) metered branch circuit that was activated by a time switch

b) replacing the existing single read out meter with a dual reading time of day meter.

The first approach would entail installation of a standard meter and a time switch on the branch circuit used to power the electric vehicle. The costs entailed would be

Meter	$ 23
Meter installation	$ 6
Time switch	$ 83
Switch installation	$ 8
Total	$120

The difference in the monthly charge in kilowatt hour readings of the two meters and the monthly charge in the reading of the branch circuit kilowatt hour reading would be used to calculate the customer's bill.

Alernately, the existing meter could be replaced by either a two register meter activated with an external clock, as detailed in Table C-3, or by a three register meter with an internal clock, as shown in Table C-4.

Comparable equipment for commercial/industrial uses would be more expensive, as shown in Table C-5.

These costs are also summarized in Table C-1.

C-4 Commercial/Institutional Users of Electric Vehicles - Recharging on Property

Commercial and institutional operators of motor vehicle fleets that have fixed or predictable mission requirements for individual vehicles have been identified as the most likely near term candidate purchasers of electric vehicles. Such operations are usually large entities that are provided with an electric service of high capacity - typically 150 kW or more. Service of this capacity in the absence of other electricity demand would be large enough to accommodate a fleet of thirteen vehicles for example. For most commercial and industrial operations, demand for electricity varies with the time of day (other than for process plants that operate around the clock). These users should have available capacity (in terms of entrance service) during their off-peak hours of operation (i.e. outside the normal business day) that should

TABLE C-3 RESIDENTIAL TIME-OF-DAY METERING USING A TWO-REGISTER METER AND AN EXTERNAL CLOCK

Item	Cost*
Two-register, three-wire, 240-volt, Class 100 kWh meter with separate terminal for shifting registers (meters of this type are available from G.E., Westinghouse, Sangamo and Duncan).	$64
Timed switch with backup capability (Sangamo WHR21A)	83
Installation of meter (estimate)	6
Installation of timed switch (estimate)	8**
Equipment handling, shop testing, records (estimate)	3
TOTAL CAPITAL COST PER INSTALLATION	$164

*As of September 1978.

**This assumes an indoor meter location with room on the supply panel for mounting the clock. Outdoor locations would result in higher installation costs.

Source: Reference C-1

TABLE C-4 RESIDENTIAL TIME-OF-DAY METERING USING A THREE-REGISTER METER WITH AN INTERNAL CLOCK

Item	Cost*
General Electric three-register meter, 240-volt, three-wire with internal clock and battery-powered backup system (type IR-70 with T-76 register)	$145
Installation of meter	4
Equipment handling, shop testing, records	5
TOTAL CAPITAL COST PER INSTALLATION	$154

*As of September 1978.

Source: Reference C-1

TABLE C-5 INDUSTRIAL/COMMERCIAL DEMAND AND TIME-OF-DAY KWH METERING USING TWO CONVENTIONAL POLYPHASE METERS AND AN EXTERNAL CLOCK

Item	Cost*
Self-contained, two-stator, 240-volt, Class 200 polyphase watthour meter (for example, Westinghouse Type D4S-2)	$ 98.05
Self-contained, two-stator, 240-volt, Class 200 polyphase demand meter (for example, Westinghouse Type D4S-2M)	156.24
Timed switch with backup capability (Sangamo WHR21A)	83.00
Installation of meters (estimate)	30.00
Installation of timed switch (estimate)	10.00
Equipped handling, shop testing (estimate)	12.00
TOTAL CAPITAL COST PER INSTALLATION	$389.29

*As of September 1978.

Source: Reference C-1

be large enough to accommodate the recharging of the limited number of electric vehicles that one could anticipate being used by such entities. Since commercial and industrial users are assessed for both peak demand and total consumption of electricity, it is unlikely that electric vehicles would be recharged during those periods of the day in which demand for electricity from other sources (non-EV) were at a maximum.

In order to be able to recharge EV's, firms would have to run branch circuits from their entry panel to the location within their plant or garage where the recharging would be performed. The costs of establishing such facilities are based on Harshberger's paper (C-2).* The electrical installation for a five vehicle recharging facility would range from approximately \$1900 to \$2900, which is equivalent to \$370 to \$570 per vehicle.

It is anticipated that recharging would be performed either in a parking garage (which would meet code requirements for multivehicle facilities) or in an outside parking lot so that special ventillation requirements, beyond those already provided, would not be required.

C-5 Private Operators of Electrical Vehicles Recharging on Own Properties

C-5-1 Introduction

The purpose of this analysis is to establish the number of home owners that have the basic facilities on their property to allow them to recharge an electric vehicle on an overnight basis. These characteristics are off-street parking and an electric service with sufficient available capacity to support the additional load represented by an E.V. Home owners without off-street parking on their property would have to find and rent the required space and facilities if they wanted to own and operate an E.V. As such, they fall in the population group discussed in Section C-6. Home owners without sufficient electricity supply would have to improve their entrance service to at least that of 100 ampere, 3 wire service, or provide a separate 60 ampere, 3 wire service that would be dedicated to EV recharging. The costs of installing these services are discussed in Reference C-2.

C-5-2 Costs

In all cases, even if the entrance service were adequate, the home owners would have to provide a separate branch circuit with a 50 ampere

*This work was performed under sub-contract by General Research Corporation, Santa Barbara, CA.

(C-2) W. C. Harshberger, "Installation Costs for Home Recharge of Electric Vehicles," Report RM 2291, General Research Corp., Santa Barbara, CA, January 1940.

capacity at 230 volt specifically for EV battery recharge. As discussed in Reference C-2, the cost of installing the branch circuit would run from $200 to $441 depending on the circumstances. In case the EV were recharged indoors, a fan, interlocked with the charger, would have to be provided, to prevent accumulation of explosive gas mixtures, as well as a fire extinguisher. These items, which would add approximately $100 to the installation costs, would not be required if the EV were recharged out of doors.

The cost of installing these facilities would increase the annual cost of ownership as follows:

Depreciation of Facility (10 year straight line)	$20 - 54
Maintenance @ 4% of Investment	8 - 22
Interest Foregone @ 10% of Investment	20 - 54
	$48 - 130

Based on a vehicle utilization of 16,000 km/yr (10,000 mi/yr), operating costs would be increased by 0.30 ¢/km to 0.80 ¢/km (0.5 ¢/mi to 1.3 ¢/mi).

C-5-3 Availability

Characteristics of the housing stock and of the population are described in great detail in the Decenial Census of the Population last taken in 1970. More recent data of sufficient accuracy for the purposes of this study are provided in the Annual Housing Survey (AHS) which has been sponsored by the U.S. Department of Housing and Urban Development and conducted by the U.S. Bureau of the Census since 1974. Each year, the Annual Housing Survey presents data for the United States and four major geographic regions, and for one of three groups of 20 selected standard metropolitan statistical areas (SMSA's) on a rotating basis as listed in Table C-6. SMSAs in Group A were surveyed in 1974 and 1977, those in Group B in 1975 and 1978, and those in Group C in 1976 and 1979. The 1976 AHS was the last survey to have been published. The data in the AHS consists of two independent samples - the national sample and the SMSA sample. The 1976 national sample consisted of approximately 82,000 designated housing units located throughout the United States. For the SMSA survey, the largest SMSA of each of the four census regions of the United States was represented by a sample of 15,000 designated housing units which were evenly divided between the central city or cities and the balance of the respective SMSA; i.e., the area not in central cities, e.g., the suburbs. All remaining SMSA's were represented by a sample of 5000 designated housing units which was divided between the central city of cities and the balance of the respective

TABLE C-6

SMSA'S INCLUDED IN ANNUAL HOUSING SURVEY

GROUP A

Albany-Schenectady-Troy, N.Y.
Anaheim-Santa Ana-Garden Grove, Calif.
Boston, Mass.*
Dallas, Tex.
Detroit, Mich.*
Fort Worth, Tex.
Los Angeles-Long Beach, Calif.*
Madison, Wis.**
Memphis, Tenn.-Ark.
Minneapolis-St. Paul, Minn.
Newark, N.J.
Orlando, Fla.
Phoenix, Ariz.
Pittsburgh, Pa.
Saginaw, Mich.
Salt Lake City, Utah
Spokane, Wash.
Tacoma, Wash.
Washington, D.C.-Md.-Va.*
Wichita, Kans.

GROUP B

Atlanta, Ga.*
Chicago, Ill.*
Cincinnati, Ohio-Ky.-Ind.
Colorado Springs, Colo.
Columbus, Ohio
Hartford, Conn.
Kansas City, Mo.-Kans.
Miami, Fla.
Milwaukee, Wis.
New Orleans, La.
Newport News-Hampton, Va.
Paterson-Clifton-Passaic, N.J.
Philadelphia, Pa.-N.J.*
Portland, Oreg.-Wash.
Rochester, N.Y.
San Antonio, Tex.
San Bernardino-Riverside-Ontario, Calif.
San Diego, Calif.
San Francisco-Oakland, Calif.*
Springfield-Chicopee-Holyoke, Mass.-Conn.

GROUP C

Allentown-Bethlehem-Easton, Pa.-N.J.
Baltimore, Md.
Birmingham, Ala.
Buffalo, N.Y.
Cleveland, Ohio
Denver, Colo.
Grand Rapids, Mich.
Honolulu, Hawaii
Houston, Tex.*
Indianapolis, Ind.
Las Vegas, Nev.
Louisville, Ky.-Ind.
New York, N.Y.*
Oklahoma City, Okla.
Omaha, Nebr.-Iowa
Providence-Pawtucket-Warwick, R.I.-Mass.
Raleigh, N.C.
Sacramento, Calif.
St. Louis, Mo.-Ill.*
Seattle-Everett, Wash.*

*Sample size of 15,000 housing units; all others are 5,000 housing units.
**Included with Group B for the first enumeration.

SMSA based on the proportionate distribution of all housing units in the entire SMSA.

The Annual Housing Survey was designed to provide a current series of information on the size and composition of the housing inventory, the characteristics of its occupants, the changes in the inventory resulting from new construction and from losses, the indicators of housing and neighborhood quality, and the characteristics of recent movers. Specific data of interest to the present study include:

1) Number of year round housing units
2) Distribution of the number of housing units per structure (1 housing unit per structure, 2-4 housing unit per structure, 5 or more housing units per structure
3) The number of owner occupied housing units
4) The number of renter occupied housing units
5) The number of owner and renter occupied units which use electricity
    a) to heat the house
    b) as cooking fuel
6) The availability of off-street parking, defined as either
    a) owner occupied housing unit with garage or carport on the property, or
    b) renter occupied housing unit where parking is included in the rental
7) The number of cars available to the household, up to 3 or more
8) The number of trucks available to the household, up to 2 or more
9) Characteristics of the commute to work trip of the head of the household, with regards to means of transportation used, and median distance travelled.

For 1976, the above data are available for the total U.S.; for each of the four census regions; for the regions outside the SMSA's sampled; for the individual SMSA's, their center city (or cities), and outside their center city (or cities), or suburbs and for the aggregate of the twenty SMSA's, for the total region of the SMSA's, their central cities and their suburbs.

For 1975, the data are similar except that the distinction between central city and suburbs was only made for the four largest cities sampled in that year. In addition to the standard survey reports, the Bureau of Census also published two special analyses on the characteristics of travel to work in the

U.S. (C-3, C-4), which combine data of interest to this study.

The 1974 survey does not distinguish between the central city and the suburbs of an SMSA, and does not provide any commuting data. It is the least complete of the three surveys published to date.

Pertinent data for the U.S. overall from the 1975 and 1976 surveys are presented in Table C-7 and C-8. In addition, twenty-one SMSA's were examined individually. These cities were chosen from the forty cities surveyed in 1975 and 1976. The lists include five SMSA's from each of the four major geographic areas of the continental U.S., as well as the Honolulu, HI SMSA. These tables also list the cost of a typical electric bill as of January 1, 1978 for each of the SMSA's of interest, from the compilation published by Energy Information Administration of the U.S. Department of Energy (C-5). The regional data will be discussed subsequently in Section C-8.

Comparison of Tables C-7 and C-8 indicates that although the housing stock of the United States increased by 2% between 1975 and 1976, there was little fundamental change in the characteristics of the way people are sheltered in this country. There is approximately one housing unit for every three inhabitants. The number of housing units are approximately evenly divided between SMSA center cities, SMSA suburbs and regions outside the SMSA's. Most of the housing units are in one unit structures (67% of all year round housing units), and only 15% of all housing units are in structures that contain 5 or more housing units. While the concentration of 1 unit structures is highest outside the SMSA's and in the SMSA suburbs, approximately 50% of the housing units in the SMSA center cities are in one unit structures. There are approximately twice as many owner occupied as renter occupied housing units for the U.S. as a whole. This ratio is approximately two and one-half for the SMSA suburbs and the regions outside SMSAs, but about one for the SMSA cities. Approximately 45 percent of the occupied rented units are in the SMSA center cities, whereas

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(C-3) "The Journey to Work in the United States: 1975", Current Population Reports, Special Studies, P-23, No. 99, U.S. Department of Commerce, Bureau of the Census, July 1979.

(C-4) "Selected Characteristics of Travel to Work in 21 Metropolitan Areas: 1975", Current Population Reports, Special Studies, P-23, No. 68, U.S. Department of Commerce, Bureau of the Census, February 1979.

(C-5) "Typical Electric Bills- January 1, 1978", DOE/EIA-0040/1, U.S. Department of Energy, Energy Information Administration, August 1979.

TABLE C-7 CHARACTERISTICS OF INTEREST OF THE U.S. HOUSING STOCK IN 1976

	U.S. Overall		Inside SMSAs		SMSA Center Cities		SMSA Suburbs		Outside SMSAs	
	Owner Occupied	Renter Occupied	Owner Occupied	Renter Occupied	Owner Occupied	Renter Occupied	Owner Occupied	Renter Occupied	Owner Occupied	Renter Occupied
Year Round Housing Units	77,553,000		52,690,000		24,205,000		28,485,000		24,861,000	
in 1 unit structures (%)	67.8		62.8		50.5		72.3		79.7	
in 5 or more unit structures (%)	15.2		20.2		27.8		13.8		1.6	
Occupied Housing Units	46,867,000	25,656,000	30,383,000	19,283,000	11,280,000	11,469,000	19,104,000	7,814,000	16,484,000	6,373,000
Above, as " Year Round Housing Units	60.4	33.1	57.7	36.6	46.6	47.4	67.1	27.4	66.3	25.6
Electricity Use										
To Heat House, % Occupied Units	10.1	15.9	7.9	16.6	6.4	14.5	8.9	19.7	15.0	13.9
As Cooking Fuel, % Occupied Units	53.6	37.5	50.8	34.5	42.7	27.8	55.6	44.3	59.6	47.8
Parking										
Owner Occupied Houses with Garage or Carport on Property, % of Occupied Units in class	73.0		75.4		73.2		76.7		67.7	
Parking Included in Rental, % of Occupied Units in class		91.1		92.6		92.9		92.1		86.3
Automobiles Available										
One (In % of Occupied Units in Class)	44.2	51.0	41.2	50.2	44.1	45.4	39.4	57.2	50.9	53.7
Two or more	47.7	19.1	51.6	18.7	45.4	14.0	55.4	25.5	38.8	20.8
Trucks Available	23.5	9.4	19.2	7.2	16.4	5.0	20.9	10.6	32.8	16.6
Median Distance from Home to Work for the Head of Household, all modes of transportation, miles	7.9	4.9	8.6	5.4	6.6	4.7	9.9	6.9	5.6	3.9
Workers Commuting by Car or Truck										
Driving Alone										
Percent of All Commuting Workers	66.6				59.9		69.7		64.4	
Mean One Way Distance, miles	8.3				7.1		9.4		7.9	
Median One Way Distance, miles	4.7				4.4		6.0		3.4	
80 Percentile One Way Distance, miles	13.4				10.8		15.0		12.1	
Car Pools										
Percent of All Commuting Workers	20.4				17.3		18.9		22.1	
Mean One Way Distance, miles	11.4				8.5		11.6		13.3	
Median One Way Distance, miles	7.2				5.0		8.6		7.8	
80 Percentile One Way Distance, miles	18.5				12.8		18.6		23.0	

TABLE C-8 PERTINENT DATA FROM THE 1976 ANNUAL HOUSING SURVEY

	U.S. OVERALL		INSIDE SMSA'S		SMSA CENTER CITIES		SMSA SUBURBS		OUTSIDE SMSA'S	
	Owner Occupied	Renter Occupied	Owner Occupied	Renter Occupied	Owner Occupied	Renter Occupied	Owner Occupied	Renter Occupied	Owner Occupied	Renter Occupied
Year Round Housing Units	79,316,000		53,606,000		24,547,000		29,059,000		25,710,000	
In 1 Unit Structures (%)	67.6		61.9		49.8		72.1		79.5	
In 5 or More Unit Structure(%)	15.0		20.1		28.0		13.3		4.4	
Occupied Housing Units	47,904,000	26,100,000	30,895,000	19,557,000	11,349,000	11,581,000	19,546,000	7,976,000	17,009,000	6,544,000
Above, as % Year Round Housing Units	60.4	32.9	57.6	36.5	46.2	47.2	67.3	27.4	66.2	25.5
Electricity Use										
To heat house, % of Occupied Units	11.6	16.4	9.0	16.9	7.0	14.8	10.1	20.0	17.1	14.9
As Cooking Fuel, % of Occupied Units	55.7	38.1	52.9	34.7	44.8	27.9	57.6	44.9	61.8	49.2
Parking Owner Occupied Houses with Garage or Carport on Property, % of Occupied Units in Class	75.5		78.0		75.6		79.4		70.0	
Parking Included in Rental, % of Occupied Units in Class		91.5		92.9		93.2		92.5		86.8
Automobiles Available (In % of occupied units in Class) One	44.1	50.7	40.9	49.5	44.4	44.8	38.9	56.5	50.8	54.3
Two or More	48.1	19.8	52.1	19.5	45.0	14.8	56.2	26.4	39.3	20.9
Trucks Available	24.9	10.1	20.8	7.5	18.5	5.4	22.1	10.7	33.7	18.5
Median Distance from Home to Work for the Head of the Household All Modes of Transportation, miles	8.3	5.2	9.0	5.9	6.7	4.9	11.0	7.5	5.9	4.0

80 percent of the owner occupied housing units are located outside the SMSA center cities.

In terms of electricity use, relatively few are electrically heated. However, over half the owner occupied units and nearly 40% of the rental units use electricity as the cooking fuel. While the survey asks questions as to the use of electricity or certain appliances (e.g. air conditioners), it does not categorize the housing stock in terms of the power rating of the entrance service. No other data sources were found for the distribution of the service rating with the housing stock. The current minimum service for new family dwellings promulgated by the National Electrical Code of the NFPA is 100 ampere three wire (230 volts) service for dwelling with six or more 2 wire branch circuits, or with an initial computed load of 10 kW or more. This service would be sufficient for an average household which uses an electric range, and a complement of common appliances (see Table C-9), but is not electrically heated. Modern "all-electric" houses have 150 ampere or 200 ampere 3 wire service. According to utility company sources, the electric service of many of the older homes (built before 1960) has been upgraded to current standards for new construction (i.e., 100 ampere 3 wire service).

A single family dwelling equipped with a 100 ampere, 3 wire service has sufficient panel capacity to support the recharging of an electric vehicle, and an equivalent combined electrical load from other household demands. It is anticipated that this should be more than ample capacity as long as other load appliances are not used simultaneously. It would not be possible to support continuous electrical demands (lighting refrigeration, furnace operation), an electric range and the recharging of an EV simultaneously without overloading the entrance service panel circuit. However it would be possible to operate any two of the three loads concurrently.

Given the absence of more detailed data on the characteristics of service supplied individual dwelling units, and the demand for electricity by the households in these units, the presence of an electric range was used as an indication of the capability of the electric service to support the recharging of an electric vehicle. An electric range draws the approximately same amount of power as an electric vehicle. Any household that has an electric range has sufficient capacity to support another appliance of equal load, as long as the other appliance is not used at the same time as the range. Any household that has an electric range therefore has a service of sufficient capacity to support

TABLE C-9 ELECTRICAL POWER DEMAND OF TYPICAL REPRESENTATIVE APPLIANCES

	Electrical Load, Watts
Lamps and Lighting (per unit)	25 - 400
Television Set	300
Refrigerator	250
Home Freezer	350
Dishwasher	1800
Garbage Disposer	300
Toaster	1100
Blender	250
Hand Iron	1000
Automatic Washer	700
Automatic Dryer (regular)	4500
Automatic Dryer (high speed)	8700
Electric Range	8000 - 16000
Hot Water Heater	2500
Central Air Conditioning	5000
Fuel Fired Furnace	800
Built-in-Room Heater	1600

the recharging of an electric vehicle during off-peak hours. Referring to Tables C-7 and C-8, at least 55 percent of the owner occupied housing units are provided with an electric service of sufficient capacity to support the off-peak recharging of electric vehicles. The percentage is lower within the SMSA center cities and higher in the SMSA suburbs and outside SMSA. It is quite possible that a much larger fraction of service occupied dwellings would have an entrance service of sufficient capacity, but the substantiating data were not obtained.

Most owner occupied units also provide off-street parking. Approximately 75 percent of all owner occupied units have a garage or carport on the property. The survey data do not include uncovered parking on the property, and do not specify the number units without any off-street parking facilities. The data on the number of owner occupied units with a garage or carport is therefore a minimum understated estimate of the number of housing units with off-street parking facilities. There is little variation in the availability of covered parking between the SMSA center cities, the SMSA suburbs and the regions outside of the SMSAs.

A measure of the number of owner occupied units where EV's could be recharged is obtained by multiplying the number of owner occupied units by the product of the fraction of the units that use electricity for cooking, by the fraction of the units that have a garage or carport on the property. These results are presented in Table C-10. According to these results, at least 40% of the owner housing units have the basic facilities required for off-peak charging of electric vehicle batteries. The proportion of owner occupied units that have the capability is 50% higher than the U.S. average in the SMSA suburbs, about average outside the SMSAs, and significantly lower than average within the SMSA center cities. On a numerical basis, it is estimated that there are approximately twenty million owner occupied housing units with the basic facilities required for EV recharge. Approximately thirteen million of these units are in the SMSAs; with nine million in the suburbs and four million in the center cities.

It is interesting to note that on a national basis, the number of owner occupied units with existing facilities for EV recharging closely matches the number of electric vehicles that could be recharged at off-peak hours by the electric utilities, as discussed in Chapter 3.

The Annual Housing Survey also provides information on the number of automobiles and trucks available in an occupied housing unit. Examination of the

TABLE C-10 CHARACTERISTICS OF OWNER OCCUPIED HOUSING UNITS THAT PERTAIN TO E.V. RECHARGING

			Percent of Owner Occupied Housing Units that			
	Year	Number of Owner Occupied Housing Units (1)	Use Electricity for Cooking (2)	Have Carport or Garage on Property (3)	Have Facilities For EV Recharge (4)	Estimated Number of Owner Occupied Housing Units with Facilities for EV Recharge (5)
U.S. Overall	1975	46,867,000	53.6	73.0	39.1	
U.S. Overall	1976	47,904,000	55.7	75.5	42.1	20,200,000
Inside SMSA's	1975	30,383,000	50.8	75.4	38.3	
Inside SMSA's	1976	30,895,000	52.9	78.0	41.3	12,800,000
SMSA Center Cities	1975	11,280,000	42.7	73.2	31.3	
SMSA Center Cities	1976	11,349,000	44.8	75.6	33.9	3,800,000
SMSA Suburbs	1975	19,104,000	55.6	76.7	42.6	
SMSA Suburbs	1976	19,546,000	57.6	79.4	45.7	9,000,000
Outside SMSA's	1975	16,484,000	59.6	67.7	40.3	
Outside SMSA's	1976	17,009,000	61.8	70.0	43.3	7,400,000

data in Tables C-7 and C-8 indicate that, on a national basis, slightly less than half of the owner occupied units have one automobile available, and approximately one quarter have one or more trucks available. Within the SMSA's center cities, an equal percentage of owner occupied units have one automobile and two or more automobiles available, with only 10% of the units without an automobile. In addition, about 18% of these units have at least one truck available. In the SMSA suburbs, there is a significant increase in the number of units with two or more cars available, a slight increase in the number of units which have a truck available, and a decrease in the number of units where one car or no cars are available. Outside the SMSAs, there is a significant decrease in the number of units with two or more cars, but a sharp increase in the number of units which have one truck available.

There are significantly more passenger automobiles and trucks available on a proportional basis in units that are owner occupied than in units that are renter occupied. On a national average, approximately one-half the renter occupied housing units have one car available, which is not markedly different than for the owner occupied units, but only 20 percent have two or more cars available, and only 10 percent have one or more trucks available. A significant fraction of renter occupied units have no motor vehicle available. Depending on the number of automobile owners that also own trucks, the percentage ranges from 20 percent to 30 percent.

The data on vehicle ownership published in the 1976 Housing Survey was used to calculate values of the average number of vehicles per occupied unit, for owner occupied and renter occupied units. These data are presented in Table C-11. As can be noted from the Table, the average number of vehicles per occupied unit is 72 percent higher on a national basis for owner occupied units than for renter occupied units. This ratio is nearly two within the SMSA center cities, even though the number of vehicles per occupied housing unit in the SMSA center cities is slightly lower than the national average for owner occupied units. Since the number of owner occupied housing units is much greater than the number of renter occupied housing units, most of the private automotive vehicles in the nation are associated with owner occupied units. In the SMSA suburbs and outside the SMSA's, approximately 80 percent of the private vehicle fleet is associated to owner occupied units. In the SMSA center cities, which have proportionately fewer owner occupied units, approximately 66 percent of the private vehicle fleet is associated with owner occupied units.

TABLE C-11 DISTRIBUTION OF AUTOMOTIVE VEHICLE POPULATION BETWEEN OWNER OCCUPIED AND RENTER OCCUPIED HOUSING UNITS 1976

	Automotive Vehicle Per Occupied Housing Unit			Occupied Housing Units as Percent Year Round Housing Units			Percent of Private Automotive Vehicles in	
	Owner Occupied Unit	Renter Occupied Unit	Year Round Housing Units	Owner Occupied Units	Renter Occupied Units	Estimated Private Automotive Vehicle Population	Owner Occupied Units	Renter Occupied Units
U.S. Overall	1.783	1.036	79,316,000	60.4	32.9	112,400,000	76.0	24.0
Inside SMSA's	1.798	0.990	53,606,000	57.6	36.5	74,900,000	49.4	17.2
SMSA Center Cities	1.646	0.820	24,547,000	46.2	47.2	28,200,000	16.6	8.5
SMSA Suburbs	1.885	1.241	29,059,000	67.3	27.4	46,800,000	32.8	8.8
Outside SMSA's	1.746	1.185	25,710,000	66.2	25.5	37,500,000	26.5	6.9

Source: 1976 Annual Housing Survey

The ratio of the fraction of owner occupied housing units that have the basic facilities for EV recharging to the average number of automotive vehicles available per owner occupied housing unit is a measure of the replacement potential fraction of ICEV's in owner occupied housing units that could be replaced with EV's, assuming home recharging facilities as the limiting factor. As shown in Table C-12, according to this criterion, it would be possible to replace approximately one quarter of ICEV's associated with owner occupied housing units with EV's. Based on the total private vehicle population, including ICEV's associated with renter occupied housing units, there are enough owner occupied housing units with basic requirements for EV recharging to support an EV fleet that would be 18 percent of the size of the private fleet of automotive vehicles that was in use in 1976. The percentage would be slightly higher in the SMSA suburbs and outside the SMSAs than in the SMSA center cities.

C-6 OPERATION OF ELECTRIC VEHICLE RECHARGING ON LEASED PROPERTY

C-6-1 Introduction

The previous section of the analysis considered the case of potential EV operators that would recharge their vehicles on their own property. This section of the analysis considers the case of potential EV operators that would have to lease their home recharging space from another party. This population would consist of:

- o individuals who do not own the housing unit they reside in.
- o home owners who do not have off street parking on their property, or who have off-street parking where it would be difficult to provide suitable electric service.
- o commercial or institutional groups that operate from leased facilities.

The support services of EV recharging could be provided by one of the following:

- o the tenant's landlord if off-street parking facilities that could be electrified were available on the property.
- o operators of commercial or municipal garages suitably converted to provide the required electrical outlets.

C-6-2 Costs

The capital investment required to provide electrical recharging outlets in multi-vehicle parking areas are discussed in Reference C-2, was estimated to range from $1890 to $2860 for a five vehicle recharging facility, or $370 to $570 per stall, depending on whether it was open or enclosed. The

TABLE C-12 POTENTIAL PENETRATION OF EV'S BASED ON OWNER OCCUPIED HOUSING UNITS WITH REQUISITE SUPPORT FACILITIES

	Number of Owner Occupied Housing Units (1)	Average Number of Automobile Vehicles per Owner Housing Unit (2)	Automotive Vehicles Available to Owner Occupied Housing Units (3)	Owner Occupied Housing Units with EV Support Capability (4)	Potential for EV Support as Percent of Number of Automotive Owner Occupied Housing Units (5)	Potential for EV Support, as Percent of Total Number of Private Vehicles (6)
U.S. Overall	47,904,000	1.783	85,400,000	20,200,000	23.7	18.0
Inside SMSA's	30,895,000	1.798	55,700,000	12,800,000	23.0	17.0
SMSA Center Cities	11,349,000	1.646	18,800,000	3,800,000	20.2	13.4
SMSA Suburbs	19,546,000	1.885	36,900,000	9,000,000	24.4	19.3
Outside SMSA's	17,009,000	1.746	29,700,000	7,400,000	24.9	19.7

rental fee over and beyond the base parking fee that the owner of the facility would charge an EV operator, based on the upper value of the capital investment and an 80 percent utilization rate, was estimated to be \$9/month to \$24/month, depending on the capital investment and ownership of the parking facility as shown in Table C-13. The charges involved are all fixed costs: depreciation, maintenance, and interest, plus a pretax profit of 20 percent of the capital investment for parking facilities owned by commercial enterprises. It is presumed that a profit would not be charged if the facility were owned by a municipality. Based on an annual vehicle use of 16,000 km (10,000 mi) the above fees would add from 0.7 ¢/km (1.1 ¢/mi) to 2.0 ¢/km (3.1 ¢/mi) to the costs of ownership of an electric vehicle.

For EV operators that were tenants in one unit or two unit dwellings the cost of recharging would be lower. They would be about 80% higher than the costs developed for the operator of an electric vehicle who owned the property where recharging occurred. The difference is due to an assumed annual profit for the property of 20 percent of the required investment. In this case the annual cost to the EV operator would be from \$7/month to \$20/month, which corresponds to 0.6 ¢/km to 1.5 ¢/km (0.9 ¢/mi to 2.5 ¢/mi) based on 16,000 km/yr (10,000 mi/yr) vehicle use.

C-6-3 Availability

Examination of Tables C-7 and C-8 indicate that 67 percent of the year round housing units in the United States were one unit structures and 15 percent were structures with five or more units. By difference therefore, 18 percent of the units were in structures with two to four units. These tables indicate further that 60% of all units are owner occupied. If it is assumed that 90 percent of the owner occupied units are in a single unit dwelling, and the balance in dwellings with 2-4 units per dwelling, then the distribution of tenants by the number of units per structure can be estimated, as shown in Table C-14. If all the owner occupied units were assumed to be in one unit dwellings, the relative numbers of renters in one unit and two to four unit dwellings would change by 15 percent of the total number of rental units.

The provision of adequate electric service for EV recharge in multi-unit dwellings and parking garages was not specifically analyzed. Given the electricity requirements of such facilities, as compared to a one-unit dwelling, it is presumed that the entrance service facilities per unit case should be ample to support the recharging of a limited number of electric vehicles during off-peak

TABLE C-13 ADDITIONAL PARKING FEES REQUIRED TO SUPPORT ELECTRIFIED PARKING

Capital investment in Electrical Equipment for a Five Stall Recharging Facility	$1850-$2850
Capital Investment in Electrical Facilities for Recharging EVs, per Parking Space	$ 370-$ 570
Capital Investment in Electrical Facilities for Recharging EVs, per Electric Vehicle, Based on an 80% Utilization Factor	$ 463-$713
	Annualized Costs, $
Depreciation, 10 year straight line	46-71
Maintenance, @ 4% of Capital Investment	19-29
Interest, @ 10% of Capital Investment	46-71
Total Annual Costs per EV to Facility Owner	111-171
Profit (@ 20% capital investment)	93-143
Total Annual Fee per EV	209-314
Monthly Parking Fee without profit	$ 9-14
with profit	$ 17-26

TABLE C-14 DISTRIBUTION OF RENTED UNITS BY NUMBER OF UNITS PER DWELLING FOR THE UNITED STATES IN 1975 & 1976

Number of Units Per Dwelling	Percent of All Year Round Housing Units	Renter Occupied Units: Percent of All Year Round Housing Units	Renter Occupied Units: Percent of Renter Occupied Housing Units
U.S. Overall			
One	67	13	33
Two to Four	18	12	30
Five or More	15	15	37
Inside SMSA's			
One	62	6	16
Two to Four	18	12	32
Five or More	20	20	53
Outside SMSA's			
One	80	20	59
Two to Four	15	9	26
Five	5	5	15

Basis of Data 1975 and 1976 Annual Housing Surveys.

hours. More specifically, in terms of parking facilities associated with renter occupied housing units, the criterion of the use of electricity as the cooking fuel can be used, but on a more constrained basis than was done for owner occupied dwelling. The projected maximum demand load specified by the National Electrical Code, as shown in Figure C-1, does not increase proportionately with the number of electric ranges in a dwelling, because a lower demand factor is applied to each incremental appliance: 8 kW for the first appliance, 3 kW for the 2nd to the 5th units, 1 kW for the 6th to the 40th unit, and 3/4 kW for every unit above 40.

Based solely on the use of electricity as a cooking fuel, the above indicates that the larger the building, the smaller the number of EVs that could be recharged off-peak per electric range in the dwelling. Based on Figure C-1, it is estimated that the service capacity would have sufficient capacity to recharge 1 EV/unit in a one unit dwelling, 0.5 EV/unit in a 3 unit building, and 0.22 EV in a 20 unit dwelling.

According to Tables C-7 and C-8 approximately 38% of the renter occupied housing units per electricity for cooking. Assuming that the use of electricity for cooking is independent of the number units in the dwelling, and using the above rating factors with the distribution of rental housing given in Table C-14, it is estimated that the electricity service to dwellingg with renter occupants would be sufficient to support 5.6 million EV's in the U.S. The derivation of this estimate is outlined in Table C-15.

It is to be noted that the percentage of units in structure with five or more units is nearly twice as high in the SMSA center cities as it is nationally. Furthermore, the use of electricity for cooking in renter units is only 27.9% for rental units in SMSA center cities as compared to 38.1% for renters on a national basis. As a result, it is anticipated that proportionally fewer EVs will be able to be recharged at renter occupied units in center cities than in renter occupied units on a national basis. Using the same procedure used for the nation as a whole, it is estimated that the electricity service to dwellings with renter occupancy in SMSA center cities would be sufficient to support 1.4 million EV's. This is one quarter of the total number, even though 44% of the renter occupied housing units are in SMSA center cities.

Another required element for EV recharge is the availability of off-street parking. As indicated in Tables C-7 and C-8, parking is available at over 90% of the rental units in the country. The percentage is slightly higher for

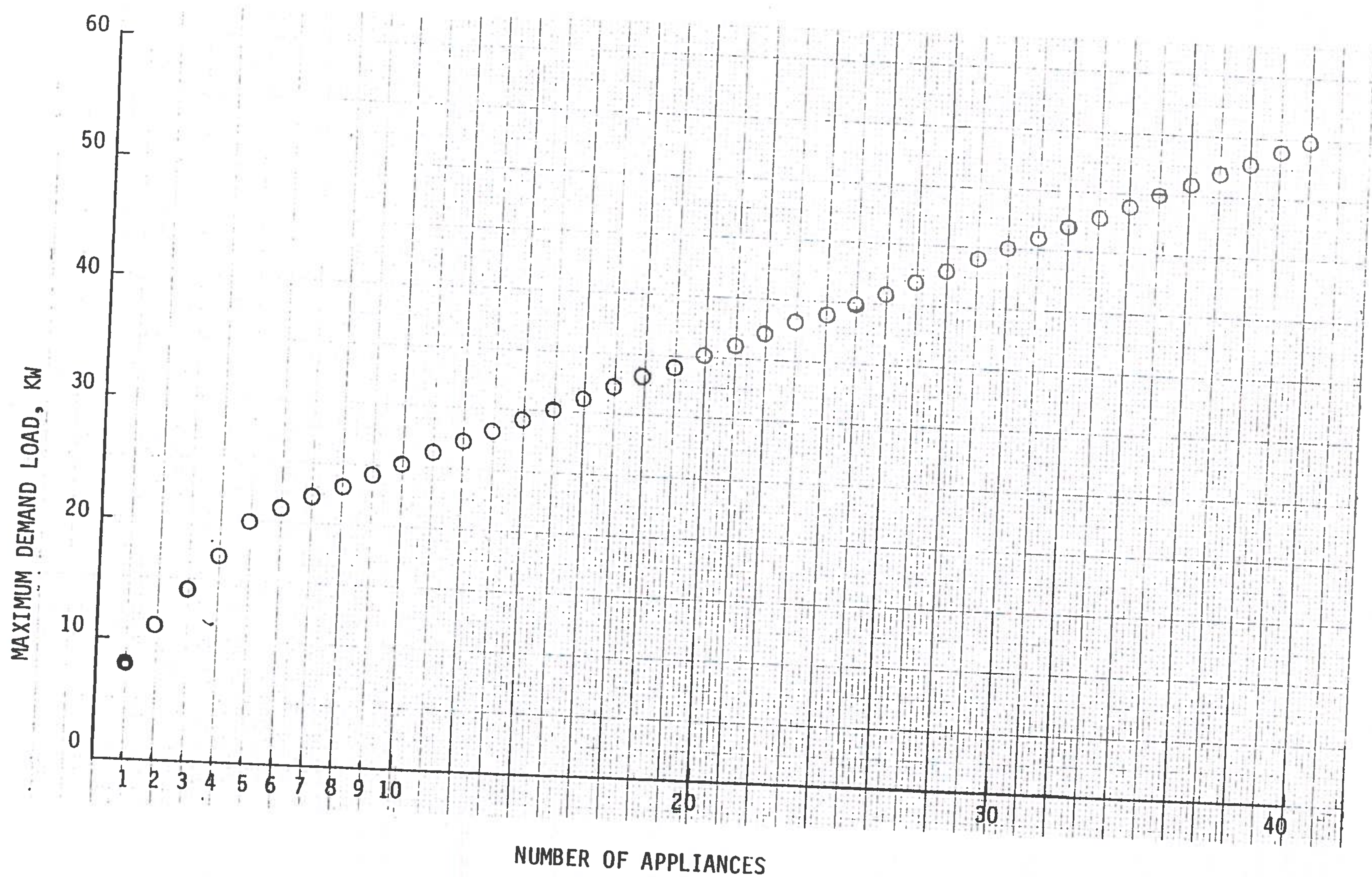

FIGURE C-1 MAXIMUM DEMAND LOAD FOR HOUSEHOLD ELECTRIC RANGES AS A FUNCTION OF THE NUMBER OF RANGES IN THE DWELLING (I.E. ON THE SERVICE) ACCORDING TO THE NATIONAL ELECTRICAL CODE

TABLE C-15 ESTIMATE OF AVAILABILITY OF ELECTRIC SERVICE FOR EV RECHARGE IN RENTER OCCUPIED HOUSING FOR THE TOTAL UNITED STATES IN 1976

Number of Units Per Dwelling	Percent of Renter Occupied Housing Units	Percent of Renter Occupied Housing Units that Use Electricity as Cooking Fuel	Electrical Capacity Rating Factor	Renter Occupied Housing Units with Electric Entrance Service Suitable for EV Recharge, as Percent of Renter Occupied Housing Units	Number of Renter Occupied Housing Units with Electric Entrance Service Suitable for EV Recharge
One	33	38.1**	1.0	12.6	3,300,000
Two-Four	30	38.1**	0.50	5.7	1,500,000
Five or More	37	38.1**	0.22	3.1	800,000
Total	100	38.1		21.4	5,600,000

*Based on a total of 26,101,000 renter occupied Housing Units.

**Assumed value equal to value for total Housing Stock.

renters inside SMSA's and slightly lower for renters outside SMSA's. By multiplying the number of electric vehicles that would be recharged at renter occupied facilities by the percentage of facilities with available parking, one obtains a measure of the number of electric vehicles that could be supported on the basis of the adequacy of the entrance electric service and availability of parking on the property. This value is equal to 5.1 million EV's on a national basis, of which 1.3 million would be in SMSA center cities. For the nation as a whole, this corresponds to 0.20 EV's per renter occupied units in SMSA center cities. In 1976, as indicated in Table C-11, there was an average of 1.04 automotive vehicles available per renter occupied housing unit. A potential EV population of 20% of the ICEV's available to renter occupied units could be recharged from existing facilities in renter occupied. This is only slightly lower than the equivalent value for owner occupied units given in Table C-12.

For the SMSA center cities, the prospects for recharging EV's at tenant occupied dwellings are poorer. The above value of 1.3 million EV's corresponds to only 0.11 EV per renter occupied housing unit. Based on the value of 0.82 automobiles per renter occupied housing unit in SMSA center cities, a potential EV population of only 13% of the ICEV's available to renter occupied units could be recharged from existing facilities.

For a property owner, providing the required electric service can be considered to be an incremental cost that is relatively small in comparison to the purchase price of an electric vehicle. For EV recharging to occur at renter occupied units, however, the landlord has to be in agreement. This makes it more difficult for a renter to consider the purchase of an electric vehicle. Unless and until EV's become fairly commonplace, the general demand for EV recharging will not exist. New renter housing facilities would not be constructed with provisions for EV recharging. Existing rental housing would not be converted to provide these facilities except in those cases where a tenant would approach his landlord with a request for such facilities, and that a mutually satisfactory agreement were reached. Finding mutually agreeably terms may be difficult during the initial stages of EV commercialization. As long as EV's remain a "rare avis", a landlord would have no assurance that the electric facilities for EV recharging would be required by another tenant once the requesting tenant moved out of the specific facility--under these circumstances, the landlord could either refuse the request, ask the tenant to install the required facilities at the tenant's expense, or provide the facilities, but charge the tenant a rental fee that would allow the landlord to regain his investment and profit within the term of the requesting tenant's lease or rental agreement. During the course of the study, twelve letters were sent to major organizations involved with housing and parking. These letters requested an appointment to discuss obstacles to EV recharging in private facilities, and possible incentives to overcome these obstacles. Two of these were sent to local government agencies, one of which (Traffic Department of the City of Boston) responded, one was sent to Harvard University, which responded, and nine were sent to large private real estate management and development firms in the Boston Area, none of which responded. Partially based on this rather fragile evidence, partially on "gut-feel", it is the considered opinion of the author (R. Kaiser) that most landlords of large apartment dwellings and complexes will not want to be bothered with providing special EV recharging facilities for a few tenants as long as there is no visible penetration of EV's in the marketplace. Landlords who control small units, where there is greater personal contact between landlord and tenant, may be more receptive. Even if the landlord were willing to allow or provide the needed circuit and outlet, the resulting cost to the tenant, especially one who would not or could no sign a long term lease (two or more years) might be so high as to discourage consummation of the deal. Even if a tenant had to pay for the installation, the landlord would be able to claim that such a lease hold improvement would become part of the building facilities, and thus would belong to him.

Since the unit cost of installing recharging facilities increases with the number of recharging outlets, facilities capable of recharging a large number of EVs will not tend to be built in anticipation of future demand. Furthermore, in large housing complexes, the presence of a large number of EV's that would be recharged concurrently might result in a total demand that might exceed the entrance capacity of entrance service and panel.

C-6-4 Offsite Overnight Recharging

For renters and property owners without suitable off street parking facilities on their property who would own or operate an electric vehicle, the recourse would be to find a suitably equipped space in an offsite parking garage. This garage could either be owned by a private enterprise or by government agency, such as a municipal parking commission.

The attitude of a commercial garage would not be expected to be significantly different than that of a landlord who provides parking places for his tenants, in that recharging facilities would be installed once a demand for these facilities existed. There may be a difference in the level of EV penetration that would elicit a response from a commercial garage operator, as compared to a specific landlord. In the absence of landlords providing electrified parking places, and in the absence of publicly owned facilities, the commercial garage operation would be able to draw on a larger population base than a landlord. The size of this population would be limited by the population density and the distance the EV owner/operator would be willing to walk from his housing unit to his electrified parking space.

Based on a discussion with members of the staffs of the Traffic Department of the City of Boston, and of the Boston Redevelopment Authority, municipal authorities might be much more receptive to providing parking facilities where EV's could be recharged overnight. In congested urban residential neighborhoods, there is a shortage of off street parking facilities, and of safe on-street parking sites, i.e., sites where the presence of parked cars does not unduly impede traffic flow, or prevent the passage of any emergency vehicles, such as fire trucks. As a result, illegally parked cars are a chronic problem to the police and traffic authorities. To reduce the number of cars in the area, a program has been initiated in which only cars with a validated "resident" decal are allowed to park in a given neighborhood. Strict reinforcement of this program has discouraged transient residents, such as students, from bringing cars into the area. It has also discouraged out-of-state registration of vehicles owned by in-town residents. In an attempt to further reduce on street parking congestion, an experimental program was initiated in which residents could park in one of the municipal garages at a very low cost, and be provided with free shuttle service from the garage to their residence. This program was not a success because of lack of interest.

As compared to the owner of an ICEV, the owner of an EV, who does not have access to private off street parking facilities, would have an additional unique incentive to use the off street parking facilities mode available, namely the ability to refuel (recharge) while parking.

C-7 COMMUTING DISTANCES

Another item of information to be found in the Annual Housing Survey is the median distance from home to work for the head of the household. While this information is not specifically applicable to EV recharging, it is of importance to the marketing of EV's. The median distance to work is of the order of 8 miles (13 km) for house-owners, and approximately 5 miles (8 km) for renters. Residents of SMSA suburbs commute longer distances than average (approx. 10 mi (16 km) for house owners and 7 miles (11 km) for renters), while residents of SMSA center cities and regions outside SMSAs, have shorter commutes. Comparison of 1976 and 1975 surveys indicated that commuting distances were greater for the 1976 sample than for the 1975 sample.

The above data are for all modes of transportation. The data from the 1975 Census are also available in a format that breaks out commuting by automotive vehicles (C-3), as shown in Table C-7. About 2/3 percent of all workers drive to work in their own cars, and another 20 percent carpool. The 80 percentile one way distance was 13.4 mi (21.4 km) for single drivers and 18.5 mi (29.6 km) for carpools on a nation wide basis.

These data indicate that the commuting requirements of most workers in the U.S. could be satisfied by an electric vehicle that met DOE's near term electric vehicle range goals, even if a conservative safety factor were applied to the nominal range of the vehicle of 75 mi (120 km). Because of the need to provide a reserve for unscheduled trips, as well as battery aging and inclement weather which will lower energy storage capacity of the battery, it is not unreasonable to assume that an electric vehicle would be used as a commuting car only if the nominal round trip distance from home to work were one-half of the nominal range of the vehicle. For a vehicle with a nominal range of 75 mi (120 km), this establishes a maximum round trip distance of 37.5 mi (60 km), or a maximum one way distance of 18.8 mi (30 km). As indicated in Table C-16, 88 percent of all workers in the United States in 1976 who commuted by car or truck, had one way trip distance of less than 30 km. The percentage was higher for workers in the SMSA center cities, and slightly lower for workers outside SMSAs.

C-8 REGIONAL ANALYSIS

The discussion of the prior sections considered in the country on a global basis, distinguishing only between urban, suburban and exurban areas. Such an analysis masks significant differences that exist in the housing characteristics for different regions of the country. The proportion of owner occupied to renter occupied housing, the use of electricity for cooking, the availability of parking, commuting patterns, will vary with size and region for different SMSA's. Some of these variations for the twenty-one SMSA's examined in the study are given in Table C-17. These data include both suburbs and center

TABLE C-16 WORKERS WITH ONE WAY COMMUTING DISTANCE OF LESS THAN 30 KM

Workers Commuting by Car or Truck	U. S. Overall	SMSA Center Cities	SMSA Suburbs	Outside SMSAs
Driving Alone				
Percent of All Commuting Workers	66.6	59.9	69.7	64.4
Percent of Workers Driving Alone with one way commute of less than 30 km (18.8 m)	88	94	87	87
Car Pools				
Percent of All Commuting Workers	20.4	17.3	18.9	22.1
Percent of Workers Carpooling with One Way Commute of Less than 30 km (18.8 mi)	81	91	80	72
Commute by Car or Truck				
Percent of All Commuting Workers	87.0	77.2	88.6	86.5
Percent of Workers who Commute in Car or Truck with One way Commute of Less than 30 km (18.8 mi)	86	93	86	83

Source of Data: The Journey to Work in the United States: 1975 (Ref C-3)

TABLE C-17 REGIONAL VARIATIONS IN THE CHARACTERISTICS OF THE HOUSING STOCK THAT APPLY TO THE OVERNIGHT RECHARGING OF ELECTRIC VEHICLES

SMSA	Year	Year Round Housing Units	Percent of Owner Occupied Year Housing Units	Percent of Owner Occupied Units That		Owner Occupied Housing Units with EV Recharge Facilities		
				Use Electricity for Cooking	Have Carport/Garage on Property	As Percent of All Owner Housing Units	As Percent of All Housing Units	Number
Atlanta, GA	1975	571,800	51.6	66.4	75.2	49.9	25.8	150,000
Birmingham, AL	1976	276,500	56.2	69.1	65.1	45.0	25.3	70,000
Buffalo, NY	1976	454,300	60.7	50.7	82.5	41.8	25.4	120,000
Chicago, IL	1975	2,423,500	52.4	21.8	84.9	18.5	9.7	240,000
Denver, CO	1976	544,900	57.1	77.5	81.5	63.2	36.1	200,000
Hartford, CT	1975	229,800	57.1	82.1	77.8	63.9	36.5	84,000
Honolulu, HI	1976	219,300	43.8	69.4	94.6	65.7	28.8	63,000
Houston, TX	1976	833,800	51.5	40.4	86.5	34.9	18.0	150,000
Indianapolis, IN	1976	409,600	60.0	52.9	81.5	43.1	25.9	110,000
Kansas City, KS-MO	1975	460,800	60.0	51.4	83.2	42.8	25.7	120,000
Las Vegas, NV	1976	132,400	56.7	62.7	66.3	41.6	23.6	31,000
New York, NY	1976	4,040,700	38.3	33.9	82.9	28.1	10.8	440,000
Oklahoma City, OK	1976	272,600	58.9	52.3	84.9	44.4	26.2	71,000
Omaha, NE-IO	1976	198,800	60.0	60.7	85.2	51.7	31.0	62,000
Providence, RI	1976	327,200	56.0	62.1	68.2	42.4	23.7	78,000
Raleigh, NC	1976	94,500	56.0	91.0	54.0	49.1	27.5	26,000
Rochester, NY	1975	301,900	62.3	56.5	85.2	48.1	30.0	91,000
St. Louis, MO-IL	1976	819,500	63.3	41.0	78.2	32.1	20.3	170,000
San Diego, CA	1975	578,800	52.6	43.6	90.9	39.6	20.8	120,000
San Francisco, CA	1975	1,248,700	49.7	56.6	94.0	53.2	26.4	330,000
Seattle, WA	1976	533,800	61.0	96.1	85.5	82.2	50.1	270,000
U.S. Overall	1975	75,553,000	60.4	53.6	73.0	39.1	23.6	18,000,000
U.S. Overall	1976	79,316,000	60.4	55.7	75.5	42.1	25.4	20,000,000

cities. The percent of owner occupied housing ranges from 35.3 percent for the New York, NY SMSA to 63.3 percent for the St. Louis, MO-IL SMSA. The use of electricity for cooking in these units ranges from 21.8 percent for the Chicago, IL SMSA to 96.1 percent for the Seattle-Everett, WA SMSA. Identifiable off-street parking for these units ranges from 54.0 percent for the Raleigh, NC SMSA to 94.6 percent for the Honolulu, HI SMSA.

The owner occupied housing units that both had identifiable off-street parking and used electricity for cooking, the criterion used for assessing EV recharging capability, as a percent of all owner occupied housing units, ranged from 18.5 percent for Chicago, to 82.2 percent for Seattle-Everett. As a percent of all housing units, the percentage ranged from 9.7 percent for Chicago to 50.1 percent for Seattle-Everett. It is to be noted that the two largest SMSAs included in the sample, New York and Chicago, were also the SMSAs in which owner occuped housing with nominally suitable facilities were the smallest fraction of either the owner occupied housing stock or of the total housing stock. Because of their size, New York and Chicago would have more housing units capable of supporting EV's than any other SMSA, except San Francisco - Oakland.

While EV's have been often placed in the context of being ideal commuting vehicles for the very large metropolitan areas of the country, the data in Table C-17 indicate that the characteristics of the housing stock in smaller SMSA's should make these the more likely areas for the use of electric vehicles. To emphasize this point, the analysis was carried to greater depth for three of the SMSA's surveyed in 1976: New York SMSA, Oklahoma City SMSA, and Seattle-Everett SMSA. Based on the criteria used in the analysis, these SMSAs respectively represent poor, average, and above average areas in terms of the availability of EV recharging facilities. The results of the analysis are summarized in Tables C-18 to C-27.

Tables C-18 to C-20 presented selected characteristics of the housing inventory in the three SMSA's obtained from 1976 Housing Survey. Similar tables were prepared for each SMSA examined. Tables C-21 and C-22 present data on availability of recharging facilities for owner occupied housing in the three SMSAs, as a percent of the number of housing units (Table C-21), and as a percent of available automotive vehicle (Table C-22). The data for the overall SMSA doe not necessarily agree with the sum of the data for the center city and the suburbs. This results from the sampling and extrapolation errors associated

TABLE C-18 SELECTED CHARACTERISTICS OF THE HOUSING INVENTORY IN

NEW YORK SMSA IN 1976

	Total SMSA		Center City		Outside Center	
	Owner	Renter	Owner	Renter	Owner	Renter
Year Round Housing Units	4,040,700		2,840,900		1,199,800	
1 unit structures (%)	30.1		12.3		72.2	
5 or more unit structures (%)	47.5		61.2		15.0	
Occupied Housing Units	1548100	2259600	704400	1959000	843700	300600
Above, as % Year Round Housing Units	38.3	55.9	24.8	69.0	70.3	25.1
Electricity Use						
To Heat House, % of Occupied Units	1.1	1.9	0.4	1.7	1.4	2.8
As Cooking Fuel, % of Occupied Units	33.9	3.8	5.8	1.9	44.9	15.6
Average Electric Bill 500 kWh/Month, 1978, $	28.80 - 42.85					
Parking						
Owner Occupied with Garage or Carport, % of Occupied Units	82.9		74.4		86.2	
Parking Included in Rental, % of Occupied Units		88.7		89.1		86.1
Automobiles Available (In % of Occupied Units in Class)						
One	39.5	32.2	54.4	29.5	33.6	49.8
Two or More	53.2	6.4	29.1	3.7	62.6	24.1
Trucks Available	5.3	0.9	2.4	0.6	6.5	3.0
Commuting to Work (As % of all Heads of Household)						
Drives Self	57.0	27.6	42.8	20.9	66.5	64.6
Carpools	11.5	5.8	9.1	5.1	13.1	9.7
Median Distance, mi.	15.1	6.1	10.6	5.7	18.7	8.4

TABLE C-19 SELECTED CHARACTERISTICS OF THE HOUSING INVENTORY IN OKLAHOMA CITY, OK SMSA IN 1976

	Total SMSA		Center City		Outside Center	
	Owner	Renter	Owner	Renter	Owner	Renter
Year Round Housing Units	272,600		157,600		115,000	
1 unit structures (%)	74.7		71.2		79.4	
5 or more unit structures (%)	16.5		19.0		13.0	
Occupied Housing Units	160,500	84,900	87,300	52,200	73,200	32,700
Above, as % Year Round Housing Units	58.9	31.1	55.4	33.1	63.7	28.4
Electricity Use						
To Heat House, % of Occupied Units	7.4	37.3	6.4	37.3	8.4	37.3
As Cooking Fuel, % of Occupied Units	52.3	53.1	50.8	51.7	54.1	55.3
Average Electric Bill 500 kWh/Month, 1978, $	17.07 - 18.14					
Parking						
Owner Occupied with Garage or Carport, % of Occupied Units	84.9		86.3		83.1	
Parking Included in Rental, % of Occupied Units		94.5		96.0		92.2
Automobiles Available						
One (In % of Occupied Units in Class)	43.7	54.3	43.0	54.6	44.3	53.7
Two or More (In % of Occupied Units in Class)	49.7	29.3	49.2	26.5	50.2	33.9
Trucks Available (In % of Occupied Units in Class)	31.9	14.8	28.5	14.0	36.5	16.1
Commuting to Work						
Drives Self (As % of all Heads of Household)	82.3	74.4	83.0	73.8	81.5	75.4
Carpools (As % of all Heads of Household)	13.5	17.4	12.5	17.6	14.7	17.1
Median Distance, mi.	8.0	5.5	7.6	5.4	8.8	5.6

TABLE C-20 SELECTED CHARACTERISTICS OF THE HOUSING INVENTORY IN SEATTLE-EVERETT SMSA IN 1976

	Total SMSA		Center City		Outside Center	
	Owner	Renter	Owner	Renter	Owner	Renter
Year Round Housing Units	533,800		236,800		317,000	
1 unit structures (%)	71.3		60.5		79.4	
5 or more unit structures (%)	19.3		28.7		12.2	
Occupied Housing Units	337,700	186,200	119,300	103,500	218,400	82,700
Above, as % Year Round Housing Units	61.0	33.6	50.4	43.7	68.9	26.1
Electricity Use						
To Heat House, % of Occupied Units	24.1	51.5	16.4	42.8	28.4	62.4
As Cooking Fuel, % of Occupied Units	96.1	89.3	95.2	85.8	96.3	93.6
Average Electric Bill 500 kWh/Month, 1978, $	5.44 - 5.84					
Parking						
Owner Occupied with Garage or Carport, % of Occupied Units	85.5		81.9		87.6	
Parking Included in Rental, % of Occupied Units		92.1		91.9		92.3
Automobiles Available (In % of Occupied Units in Class)						
One	43.1	52.9	47.4	50.5	40.7	55.9
Two or More	50.3	22.6	42.0	16.1	55.1	30.8
Trucks Available	33.1	13.0	21.1	7.3	39.7	20.2
Commuting to Work (As % of all Heads of Household)						
Drives Self	74.9	64.7	68.9	51.6	77.6	77.9
Carpools	16.4	13.0	16.4	13.0	16.4	13.0
Median Distance, mi.	11.6	6.9	7.0	4.6	14.9	10.2

TABLE C-21 EV RECHARGE SUPPORT CAPABILITY OF OWNER OCCUPIED HOUSING IN THREE SELECTED SMSA'S

	Number of Owner Occupied Housing Units	Percent of Owner Occupied Housing Units That: Use Electricity for Cooking	Have Carport or Garage on Property	Have Facilities for EV Recharge	Estimated Number of Owner Occupied Housing Units with Facilities For EV Recharge
New York SMSA					
Center City	704,400	5.8	74.4	4.3	30,000
Suburbs	843,700	44.9	86.2	38.7	330,000
Overall	1,548,100	33.9	82.9	28.1	430,000
Oklahoma City SMSA					
Center City	87,300	50.8	86.3	43.8	38,000
Suburbs	73,200	54.1	83.1	45.0	33,000
Overall	160,500	52.3	84.9	44.0	71,000
Seattle-Everett SMSA					
Center City	119,300	95.2	87.6	83.4	99,000
Suburbs	218,400	96.3	81.9	78.9	170,000
Overall	337,700	96.1	85.5	82.2	277,000

TABLE C-22 POTENTIAL REPLACEMENT OF ICEV'S BY EV'S BASED ON EV RECHARGE CAPACITY AT OWNER OCCUPIED HOUSING IN THREE SELECTED SMSA'S

	Number of Owner Occupied Housing Units	Average Number of Automotive Vehicles Per Owner Occupied Housing Units	Automotive Vehicles Available to Owner Occupied Housing Units	Owner Occupied Housing Units with EV Support Capabilities	Potential for EV Support As Percent of Automotive Vehicles At Owner Occupied Housing Units
New York SMSA					
Center City	700,400	1.199	845,000	30,000	3.6
Suburbs	843,700	1.813	1,530,000	330,000	21.6
Overall	1,548,100	1.641	2,540,000	430,000	16.9
Oklahoma City SMSA					
Center City	87,300	1.860	162,000	38,000	23.4
Suburbs	73,200	1.957	143,000	33,000	23.0
Overall	160,500	1.906	306,000	71,000	23.2
Seattle-Everett SMSA					
Center City	119,300	1.634	195,000	99,000	50.8
Suburbs	218,400	2.085	455,000	170,000	37.3
Overall	337,700	1.922	649,000	277,000	42.7

with a limited survey. The largest discrepancy is observed for the data for the New York SMSA. The percentage of units reported using electricity for cooking appears to be low. The above notwithstanding, there are noticeable differences in the percentage of owner occupied units that could recharge in the three SMSAs.

Tables C-23 to C-26 estimate the EV support capacity associated with renter occupied units in the three SMSAs. These data are compared to the number of automotive vehicles available to renter occupied units in Table C-26, which is comparable to Table C-22 for owner occupied units. The results of Tables C-22 and C-26 are summed in Table C-27 which presents the potential for replacement of ICEV's for all three SMSA's based on all occupied housing.

The potential for support of EV's within the center city of New York SMSA which has a large proportion of renters in large multi-unit dwellings, is very low. The support for EV's in that SMSA would be based mainly on home owners in the suburbs. In the Oklahoma City SMSA, the percentages of the housing stock that could support EV's is much higher than in the New York SMSA mainly because of differences in the characteristics of the housing stock in the center city. The potential in the Seattle SMSA is highest of all because of the dominance of single unit homes, and the nearly universal use of electricity as a cooking fuel.

TABLE C-23 EV RECHARGE SUPPORT CAPABILITY OF RENTER OCCUPIED HOUSING IN NEW YORK SMSA

	Total SMSA Number of Units Per Dwelling				SMSA Center City Number of Units Per Dwelling				SMSA Suburbs Number of Units Per Dwelling			
	Total	One	Two - Four	Five or More	Total	One	Two - Four	Five or More	Total	One	Two - Four	Five or More
Year Round Housing Units	4,040,700				2,840,900				1,199,800			
Percent of Year Round Housing Units	100.0	30.1	22.4	47.5	100.0	12.3	26.5	61.2	100.0	72.2	12.8	15.0
Renter Occupied Housing Units, as Percent Year Round Housing Units	55.9	-	11.2	44.7	69.0	-	11.6	57.4	25.1	-	10.8	14.3
Renter Occupied Units That Use Electricity as Cooking Fuel, as Percent of Renter Occupied Units	3.8				1.9				15.6			
Renter Occupied Units with Electric Service for EV Recharge as Percent of Year Round Housing Units	0.6	-	0.2	0.4		-	0.1	0.2		-	0.8	0.5
Renter Occupied Units with Parking Included in Rent, as Percent Renter Occupied Units	88.7				89.1				86.1			
Renter Occupied Units with Support Facilities for EV Recharge	21,000	-	8,000	13,000	9,000	-	3,000	6,000	14,000	-	9,000	5,000
As Percent All Year Round Housing Units	0.5	-	0.18	0.32	0.30	-	0.10	0.2	1.1	-	0.7	0.4

TABLE C-24 EV RECHARGE SUPPORT CAPABILITY OF RENTER OCCUPIED HOUSING IN OKLAHOMA CITY SMSA

	Total SMSA Number of Housing Units Per Dwelling				SMSA Center City Number of Housing Units Per Dwelling				SMSA Suburbs Number of Housing Units Per Dwelling			
	Total	One	Two - Four	Five or More	Total	One	Two - Four	Five or More	Total	One	Two - Four	Five or More
Year Round Housing Units	272,600				157,600				115,000			
Percent of Year Round Housing Units	100.0	74.7	8.8	16.5	100.0	71.2	9.8	19.0	100.0	79.4	7.6	13.0
Renter Occupied Housing Units as Percent Year Round Housing Units	31.1	8.3	7.9	14.9	33.1	7.6	8.7	16.8	28.4	9.4	7.0	12.0
Renter Occupied Housing Units that Use Electricity as Cooking Fuel as Percent of Renter Occupied Units	53.1				51.7				55.3			
Renter Occupied Housing Units with Electric Service for EV Recharge as Percent of Year Round Housing Units		4.4	2.1	1.7		3.9	2.2	1.9	55.3	5.2	1.9	1.5
Renter Occupied Housing Units with Parking Included in the Rent as Percent of Renter Occupied Units	94.5				96.0				92.2			
Renter Occupied Units with Support Facilities for FV Recharge	20,000	11,000	5,000	4,000	12,000	6,000	3,000	3,000	8,000	5,000	2,000	1,000
As Percent All Year Round Housing Units	7.8	4.2	2.0	1.6	7.8	3.8	2.2	1.8	7.9	4.8	1.8	1.3

TABLE C-25 EV RECHARGE SUPPORT CAPABILITY OF RENTER OCCUPIED HOUSING IN SEATTLE-EVERETT SMSA

	TOTAL SMSA				SMSA Center City				SMSA Suburbs			
	Number of Housing Units per Dwelling				Number of Housing Units per Dwelling				Number of Housing Units Per Dwelling			
	Total	One	Two - Four	Five or More	Total	One	Two - Four	Five or More	Total	One	Two - Four	Five Or More
Year Round Housing Units	553,800				236,800				317,000			
Percent of Year Round Housing Units	100.0	71.3	9.4	19.3	100.0	60.5	10.8	28.7	100.0	79.4	8.4	12.2
Renter Occupied Housing Units as Percent Year Round Housing Units	33.6	6.5	8.9	18.2	43.7	6.5	10.1	27.0	26.1	6.5	8.0	11.6
Renter Occupied Housing Units that Use Electricity as Cooking Fuel as Percent of Renter Occupied Units	89.3				85.8				93.6			
Renter Occupied Housing Units with Electric Service for EV Recharge as Percent of Year Round Housing Units		5.8	4.0	3.6		5.6	4.3	5.1		6.1	3.7	2.4
Renter Occupied Housing Units with Parking Included in the Rent, as Percent of Renter Occupied Units	92.1				91.9				92.3			
Renter Occuped Units with Support Facilities for EV Recharge	60,000	30,000	20,000	18,000	32,000	12,000	9,000	11,000	36,000	18,000	11,000	7,000
As Percent All Year Round Housing Units	12.3	5.3	3.7	3.3	13.5	5.1	4.0	4.7	11.4	5.6	3.5	2.2

TABLE C-26 POTENTIAL REPLACEMENT OF ICEV'S BY EV'S BASED ON EV RECHARGE CAPACITY AT RENTER OCCUPIED HOUSING IN THREE SELECTED STATES

	Number of Renter Occupied Housing Units	Average Number of Automotive Vehicles Per Renter Occupied Housing Units	Automotive Vehicles Available To Renter Occupied Housing Units	Renter Occupied Housing Units EV Support Capabilities	Potential for EV Support As Percent Of Automotive Vehicles at Renter Occupied Housing Units
New York SMSA					
Center City	1,959,000	0.378	740,000	9,000	1.2
Suburbs	300,600	1,043	314,000	14,000	4.5
Overall	2,259,600	0,467	1,055,000	21,000	2.0
Oklahoma City SMSA					
Center City	52,200	1.262	69,000	12,000	18.2
Suburbs	32,700	1,441	47,000	8,000	17.0
Overall	84,900	1.330	113,000	20,000	17.7
Seattle-Everett SMSA					
Center City	103,500	0.929	96,000	32,000	33.3
Suburbs	82,700	1.439	119,000	36,000	30.3
Overall	186,200	1.154	215,000	68,000	31.6

TABLE C-27 POTENTIAL REPLACEMENT OF ICEV'S BY EV'S BASED ON EV RECHARGE CAPACITY IN ALL OCCUPIED HOUSING IN THREE SELECTED SMSA'S

	Number of Occupied Housing Units	Number of Available Automotive Vehicles	Occupied Housing Units with EV Support Capacity		Potential For EV Support As Percent of Automotive Vehicles At Occupied Housing Units
			Number	Percent of Occupied Housing Units	
<u>New York SMSA</u>					
Center City	2,663,400	1,585,000	39,000	1.5	2.5
Suburbs	1,144,300	1,844,000	344,000	30.1	18.7
Overall	3,807,700	3,595,000	451,000	11.8	12.5
<u>Oklahoma City SMSA</u>					
Center City	139,500	231,000	50,000	35.8	21.6
Suburbs	105,900	190,000	41,000	38.7	21.6
Overall	245,400	419,000	91,000	37.1	21.7
<u>Seattle-Everett SMSA</u>					
Center City	222,800	291,000	131,000	58.8	45.0
Suburbs	301,100	574,000	206,000	68.4	35.9
Overall	523,900	864,000	345,000	65.1	39.9

APPENDIX D

REPORT OF INVENTIONS

No new innovations, discoveries, improvements or inventions were made or patents submitted on the basis of the work performed under this contract.